

EXHIBIT 1



SCIENTIFIC INVESTIGATION REPORT

Jacob Sean Barben v. Federal Cartridge Company et al.

Ct. Case No.: 1:16-CV-00094-DN
Rep./Ins.: Federal Cartridge Company
Loss Location: Bear River Pheasant Hunting Grounds, Elwood, Utah
Date of Loss: October 30, 2014
AEI Project No.: 13131





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Report Prepared for:

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AEI Corporation

A handwritten signature in black ink, appearing to read "Shawn A. Sapp", is written over a horizontal line.

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June 29, 2017

Date

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INTRODUCTION

At your request, AEI Corporation (AEI) performed a scientific investigation into the cause of a shotgun barrel burst that occurred on October 30, 2014. According to provided information, Jacob Barben was pheasant hunting with friends/coworkers and on firing his second shot of the day, the lower barrel of his Berretta over/under shotgun burst and resulted in severe injuries to his left hand. This report provides a description of our investigation and findings to date.

BACKGROUND

The following background information is based on this writer's understanding of direct communications, file information, and documents provided to date.

On October 30, 2014, Jacob "Jake" Barben went pheasant hunting with Ryan Marx, Mark Braddy, and Brian Smith at the Bear River Bottoms Hunting Club in an area east from 8800 North River Road in Elwood, Utah. All four hunters were shooting a variety of 12 gauge (12G) shotguns and all were reportedly using ammo from the same case of Federal Ammunition (Federal) Game Shok, Game Load 12G, 2 $\frac{3}{4}$ ", 1 oz., #6 shot rounds (Federal model "H121 6" shells). Mr. Barben was shooting a Berretta Silver Pigeon II, break action, over/under-style shotgun (Serial Number U30798B) with the lever set to fire the lower barrel first.

It is unclear whether or not Stephanie Thompson, of Bear River Bottoms Hunting Club, accompanied the hunters into the pheasant field or joined them later after the incident as accounts differ on that detail. As the four hunters approached the hunting grounds, a first bird took flight and Mr. Barben and one of the other hunters shot simultaneously and felled this first bird, although it was not clear to the hunters who had felled this first bird. After this first shot, Mr. Barben reloaded the lower barrel and continued on the hunt, when a second bird took flight and Mr. Barben shot at this bird, but felt an unusual recoil from the gun, then merely sat or laid down on the ground as he realized something had gone wrong. Mr. Barben's hunting companions stated that the side of the lower barrel had exploded and injured Mr. Barben's left hand. The responding officer (R. Riser) from the Box Elder County Sheriff's Office reported that he collected: all the parts of Mr. Barben's gun that could be found, the spent shotgun shell that had been removed from Mr. Barben's gun by Stephanie Thompson, and a compacted wad that had been located by Brian Smith. Mr. Barben was eventually transported to Ogden Regional Hospital for medical treatment.

INVESTIGATION TASKS

The following tasks have been performed by AEI to date:

1. Ammunition research of exemplar and other 12G and 20G shotshells, including a preliminary inspection and analysis of exemplar shotshells at AEI in Littleton, Colorado on January 27, 2017.

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2. Joint, destructive laboratory examination of the subject shotgun at AEI in Littleton, Colorado on February 6, 2017 (Day 1) and at Kilgore Engineering in Englewood, Colorado on February 7, 2017 (Day 2).
3. Non-destructive examination of the various shotshell artifacts at AEI in Littleton, Colorado on June 14-16, 2017.
4. Review of the below itemized documents and files.

REVIEWED ITEMS

The following items were provided or gathered for review, in whole or in part:

1. Second Amended Complaint, Jacob Sean Barben v. Beretta USA CORP., et al. Case No.: 150904895, 2nd Judicial District Court, Weber County, Utah.
2. Riley Alan Riser, *Box Elder County Sheriff's Office Incident Report, Incident Number 14-004369*, May 11, 2016.
3. Deposition of Jacob Sean Barben, Civil No. 150904895, Taken On May 23, 2016.
4. Deposition of Allison Barben, Civil No. 150904895, Taken On May 23, 2016.
5. Plaintiff's initial disclosures, Civil No. 150904895.
6. Plaintiff's discovery responses, Civil No. 150904895.
7. Federal's responses to plaintiff's discovery, Civil No. 150904895.
8. JSB000279-291 Incident Location Photos, Civil No. 150904895.
9. Plaintiff's expert disclosures, including scanned notes by Tom Roster, Civil No. 150904895.
10. 915 digital photographs, 203 digital microscopy images, 4 x-ray radiographs, 19 SEM images, 17 EDS spectra and 16 Fourier-transform infrared (FTIR) spectra taken by this writer from lab exams reference above.
11. *Tom Roster (Conslt) FINAL Report re. Shotgun 11-13-2016*, Tom Roster's Shotgun Report, November 13, 2016.
12. *Tom Roster (Consultant) FINAL Report re. Ammunition 11-20-2016*, Tom Roster's Ammunition Report, November 20, 2016.
13. *Re: Barben Case, Tom Roster Second Report 05-12-2015*, Tom Roster's Wad Recovery Report, May 12, 2015.
14. Deposition of Thomas A. Roster, Civil No. 1:16-CV-00094-DON, Taken On Tuesday, May 23, 2017.

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15. Tom Roster, *GUN DAMAGE: How To Check For It And Prevent It*. Clay Target Nation, May 2016, p.46-49.
16. *NFPA 921: Guide for Fire & Explosion Investigations, 2014 Edition*. Quincy, MA, National Fire Protection Association.
17. *ASTM E1188-11: Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator*. West Conshohocken, PA: ASTM International, 2011.
18. *ASTM E1020-96(2006): Practice for Reporting Incidents that May Involve Criminal or Civil Litigation*. West Conshohocken, PA: ASTM International, 2006.
19. *ASTM E1492-05: Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory*. West Conshohocken, PA: ASTM International, 2005.
20. *ASTM E860-07(2013) e1: Standard Practice for Examining And Preparing Items That Are Or May Become Involved In Criminal or Civil Litigation*. West Conshohocken, PA: ASTM International, 2013.
21. *ASTM E620-11: Practice for Reporting Opinions of Scientific or Technical Experts*. West Conshohocken, PA: ASTM International, 2011.
22. *ASTM E678-07(2013) e1: Standard Practice for Evaluation of Scientific or Technical Data*. West Conshohocken, PA: ASTM International, 2013.

LABORATORY EXAMINATION & TESTING

On February 6-7, 2017, this writer hosted a joint destructive examination of the subject shotgun (see Figure 1) that was attended and video/audio recorded by Jessica Andrew of Lance Andrew, PC (Plaintiff's legal counsel). The entire first day of the examination was held at AEI's Littleton, Colorado facilities and was also attended by Tyler Snow of Christensen and Jensen (Federal's legal counsel) and Tim Sandmeier of AEI to assist this writer in the examination proceedings. The entire second day of the examination was held at Kilgore Engineering/Spectrum Forensics in Englewood, Colorado and was again attended and filmed by Ms. Andrew with Mr. Snow also in attendance. Dr. Bastiaan Cornelissen and Mr. Dustin Turnquist of Spectrum Forensics assisted this writer throughout the proceedings of the second day's exam. On June 14-16, 2017, this writer also performed a non-destructive examination of a collection of ammo artifacts provided by Plaintiff's legal counsel. A total of 915 digital photographs, 194 digital microscopy images, four x-ray radiographs, four borescope images, 19 SEM images, 17 EDS spectra, and 16 Fourier-transform infrared (FTIR) spectra were taken during these examinations and digital copies of these files are produced herewith.

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Figure 1. The subject shotgun as delivered by Jessica Andrew (of Lance Andrew, P.C., Plaintiff's counsel) for the joint destructive examination held at AEI on February 6, 2017, with the apparent lower barrel burst highlighted by the yellow dashed ellipses (CW from top-left: 13131 SAS 2-002, 13131 SAS 2-025, 13131 SAS 2-046, 13131 SAS 2-057, and 13131 SAS 2-009).

The purpose of the two-day shotgun examination was to perform a joint, destructive inspection and disassembly of the subject Berretta firearm in the region of the lower barrel burst with microscopic imaging, chemical testing of barrel residues, and metallurgical testing of barrel surfaces and materials. Specifically, the shotgun examination focused on the careful, step-by-step analysis of the apparent barrel burst zone residues and sectioning (cutting) of the fore-end barrel assembly to open the lower barrel over a region of interest to facilitate further inspection and testing of the inner diameter (ID) barrel surfaces. This destructive testing of the subject shotgun was necessary to make a more thorough determination on the cause of this incident, but all care was used to first exhaust non-destructive means of evaluation before proceeding with destructive methods, which were carried out in accordance with ASTM standard E860 cited above. The inspection, testing, and analysis was conducted by employing a combination of techniques including visual examination and measurement, digital photography, digital-camera microscopy, digital optical microscopy, FTIR spectroscopy and microscopy, scanning electron microscopy (SEM) with energy-dispersive spectroscopy (EDS, for elemental analysis), and micro-hardness testing.

The purpose of the multi-day ammo artifact examination was to perform a non-destructive inspection and analysis of the various shotshell artifacts that have been represented as having been collected at or near the

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site of the incident. The primary focus of these inspections was on 1) the spent, Federal Game Shok, #6 shot, 2¾“, 12G shot-shell hull, labeled as item “8009” that was reportedly collected from the subject shotgun immediately following the incident, and 2) the heavily damaged and degraded plastic shot-shell tube or “separated hull” that is missing its metal head and base wad, and was reportedly found near the site of the incident approximately seven months later after a number of unknown agricultural activities had taken place at the location including a controlled burn of the field. It should be stated that this writer has seen no photographic evidence or other applicable documentation that would connect this latter, “separated hull” artifact to this incident other than Mr. Barben’s statements and Mr. Roster having tentatively identified markings on the red plastic tube that appear to match those of the “8009” artifact and exemplar shotshells.

For the purposes of clarity and simplicity, a number of measurement, directional, and orientation conventions will be consistently used throughout this report. All units of length are reported in decimal inches (*e.g.*, 3.54”), all distances along the fore-end barrel assembly or barrel sections are reported with reference to the breech end of the barrel as the 0.00” location, “upstream” will be used to represent the direction going toward the breech end, and “downstream” will be used to represent the direction going toward the muzzle end of the shotgun. All references to the hours on a clock face (*e.g.*, 4 O’clock), left side, right side, top, bottom, upper barrel, or lower barrel will be from the perspective of a right-handed shooter holding the shotgun in an upright and normal shooting position and looking from the breech end to the muzzle end.

Shotgun Exam, Day 1 – Examination, Sectioning, & FTIR Analysis

The examination began with receiving, inspecting, and documenting the contents of the subject gun case, including attendant documents and tags as pictured in Figure 1. The receiver and what remained of the fore-end barrel assembly (wooden parts were completely fractured away) were laid out for visual inspection and documentation, and chalk was used to highlight barrel markings and impressions to improve their visibility during photographic documentation. Basic measures of lengths and various dimensions were made using a combination of rules, tapes, and digital calipers as needed throughout the examination. To ensure the proper measurement and registration of distances along the barrel assembly, a red paint marker was used to place hash marks every half inch, starting from the breech end (being 0.00”) and continuing the entire length of the barrels and onto the choke tubes. These half-inch markings were placed along the 5 O’clock position of the lower barrel and along the 10 O’clock position of the upper barrel with numerical indications marked for the 6”, 12”, 18”, and 24” hash marks.

Figure 2 shows photos of the apparent lower barrel burst zone that started visibly from about the 9 O’clock position at 4.2” and ran to the 7-8 O’clock position at 7.1” for a total fracture length of ~2.9”. The widest separation of the burst zone fractures was just under 1” and was located at ~5.8”, near the mid-point of the fracture length. The left photo in Figure 2 shows a yellow arrow to indicate an apparent circumferential ring bulge centered at ~4.9”, located within the upstream end of the burst zone.

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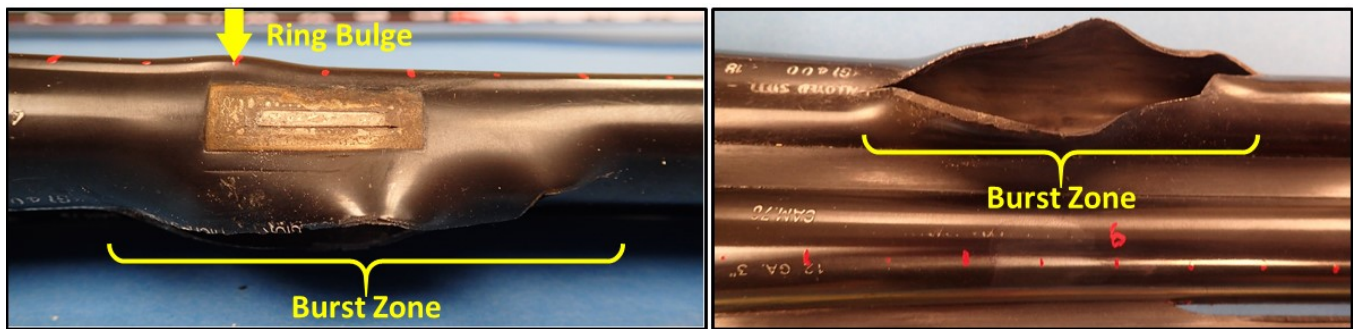


Figure 2. Photos of the lower barrel burst zone (yellow brackets) and ring bulge (yellow arrow) as seen from different angles with half-inch markings applied to the barrels in red paint marker prior to any destructive testing or inspection (13131 SAS 2-105 and 13131 SAS 2-127).

The left photo in Figure 3 shows a direct view of the barrel burst zone with a yellow arrow to indicate the location of visible, adhered barrel residues just inside the upper fracture surface. These residues were described by Mr. Roster as appearing “organic” and consistent with vegetative matter from the incident site. To this writer’s eyes, and with the aid of a 10x jeweler’s loop, these residues appeared distinctly yellow, reflective, translucent, and with a globular morphology. The red arrow in the left photo of Figure 3 shows the location of a less obvious region of barrel residues that were red, translucent, and with a fibrillar morphology, just inside the lower fracture surface, which were only visible with magnification. Digital optical microscope images at low magnification are shown on the right side of Figure 3, with black arrows indicating their respective locations from the photo at left.

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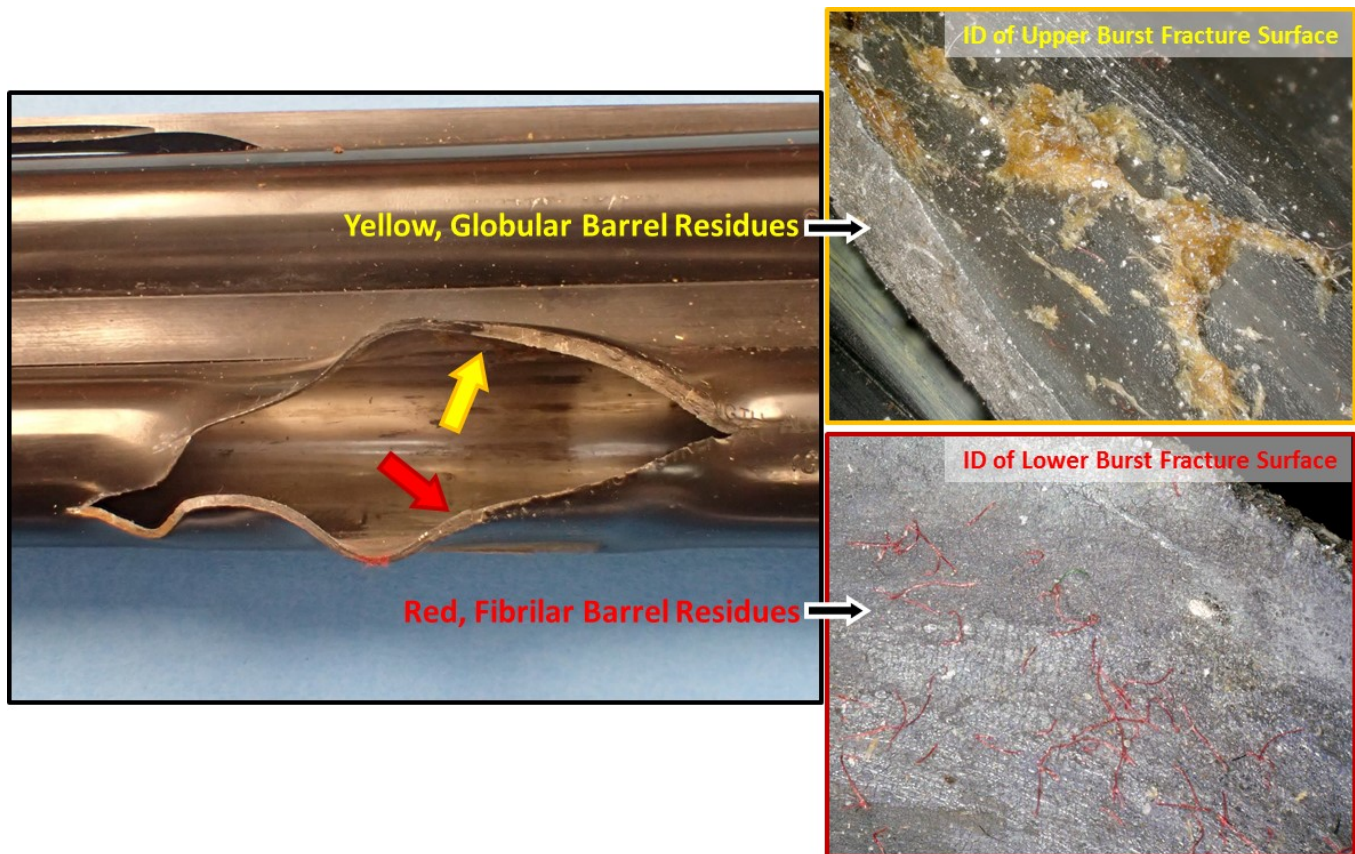


Figure 3. Photo of the lower barrel burst zone (at left, 13131 SAS 2-045) with colored arrows to indicate the location of two visibly different internal barrel residues that were imaged in the optical microscope before any destructive testing (at right). More detailed microscopy imagery of these residues is provided in the following two figures below.

A set of higher magnification images of the yellow globular residues is provided in Figure 4 in which the distinctly yellow-colored, translucent character of the upper fracture ID residues is more obvious. With the naked eye, these yellow deposits did appear to have a matte or dispersive surface sheen, but with magnification and appropriate lighting, the shiny, reflective, yellow-coloration, and translucency, all became more evident. In the higher magnified view (Figure 4, right) the globular morphology is still apparent, but it is also combined with a dendritic morphology in which fibrillar extensions can be seen spanning the distances between globular deposits. There were also small brown particulate inclusions that could be seen in the translucent portions of the yellow residues, however, these were not readily captured in the images of Figure 4. The small red arrows in the right image of Figure 4 indicate the locations of less obvious red, translucent fibers that were dispersed intermittently, but uniformly around the yellow globular deposits.

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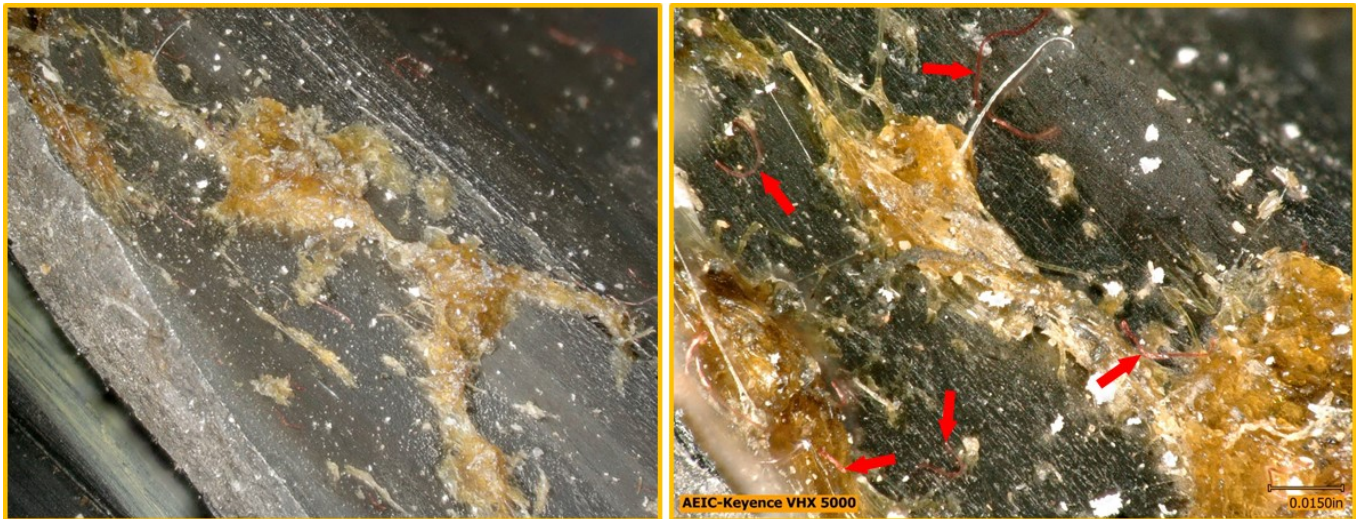


Figure 4. Keyence digital optical microscopy images of the globular, barrel residue from just inside the upper burst zone fracture at low magnification (at left) and at high magnification (at right) showing the translucency of the globular and dendritic deposits looking like melted yellow plastic; the red arrows indicate the locations of individual, red translucent fibers like those found primarily on the lower burst zone fracture surface shown in the figure below.

In contrast to the yellow-colored, globular deposits that appeared to be well adhered to the barrel ID surfaces, the dispersed, red-colored, fibers appeared to be only loosely attached and unmixed with the yellow deposits. Figure 5 shows the higher magnification microscopy images of the other barrel residue location, just inside the lower fracture surface where there appeared to be only the loosely adhered, red-colored, translucent fibers. Again, the higher magnification view at right shows the distinctly translucent and reflective character of the fibers as well as their irregular shapes/curvature and lengths.

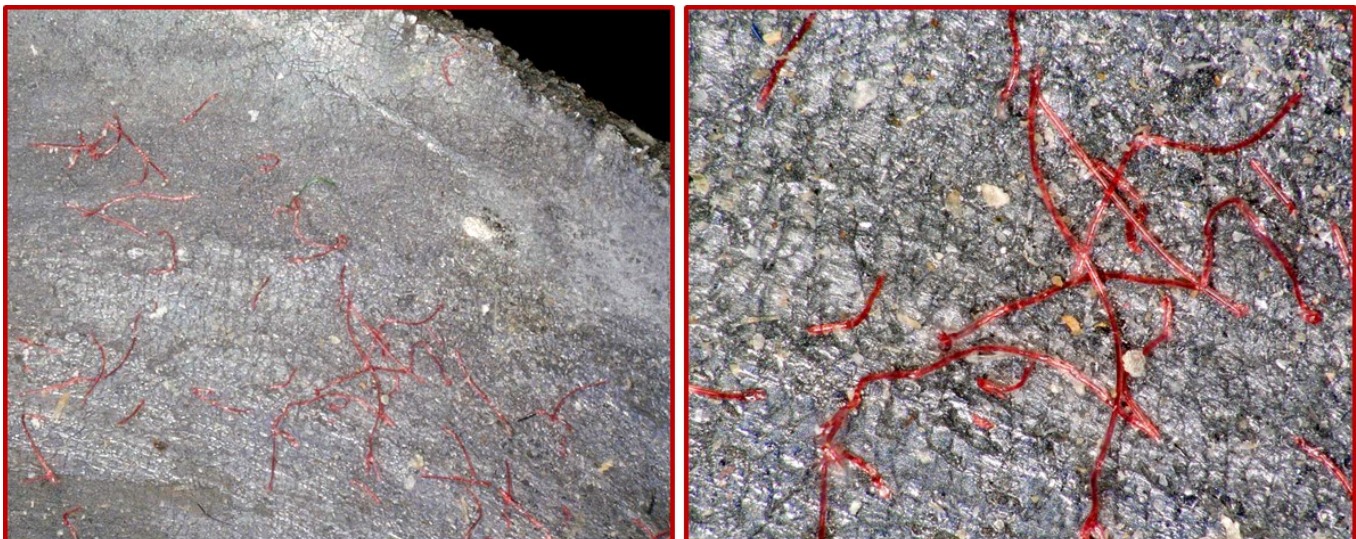


Figure 5. Keyence digital optical microscopy images of the red, fibrillar, barrel residues from just inside the lower burst zone fracture at low magnification (at left) and at high magnification (at right) showing the translucency and fibrillar morphology of the deposits.

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Samples of both the globular yellow and fibrillar red barrel residues were carefully collected from the two deposit zones (upper and lower ID of burst zone fractures) using a bamboo applicator stick to gently dislodge and collect the residues into two small zip-seal bags for later analysis with the FTIR spectrometer. Samples of the residues were collected at this stage in case contact with a borescope probe or the vibrations from later sectioning steps caused them to come loose and possibly be lost. As a part of the residue collection process, this writer observed that the yellow, globular residues were well adhered to the ID barrel surfaces, and these were somewhat rigid and brittle once dislodged for collection. The red fibrillar residues were more easily dislodged from the ID barrel surfaces and were found to be quite flexible and resilient relative to the yellow, globular residues. In contrast to Mr. Roster's observations that the residues appeared to have the character of a natural or biological organic matter, this writer observed the two subject residue materials to possess a distinctly synthetic organic character similar to melted or heat-affected plastics.

After inspecting, documenting, imaging, and collecting barrel residue materials, the examination continued with Mr. Sandmeier recording four different x-ray images of the internal mechanics of the shotgun receiver artifact, and these revealed no apparent problems or abnormalities, so the inspection continued with the focus on continuing to mark up the barrel assembly in preparation for deciding on cut locations and methods. Since 12G shotgun barrel bursts can sometimes occur as a result of barrel obstructions caused by the accidental insertion of a 20G shotshell that falls forward of the 12G chamber and becomes lodged in the region of the barrel forcing cone, it was important to document the 20G shotshell insertion depth and extent locations on the subject barrel assembly. Figure 6, left, shows a photo of an Estate-brand 20G, 2 $\frac{3}{4}$ " shotshell (HV20 6) that was dropped under gravity and came to rest within the forcing cone region of the upper barrel tube (see yellow dashed circle). The depth to the metal head of the 20G shotshell was gauged at 3.54" and with the measured 20G shotshell length of 2.28", the extent of the 20G insertion ran to 5.82". The right photo of Figure 6 shows the white paint marker registrations that were applied to upper barrel as visual references. Similarly, the insertion of an exemplar Federal Game-Shok, 12G, 2 $\frac{3}{4}$ " shotshell was also gauged and found to be flush with the rear of the breech end of the barrel assembly, and this together with the measured 2.28" length of the shell was marked in red paint marker registration lines for visual reference.

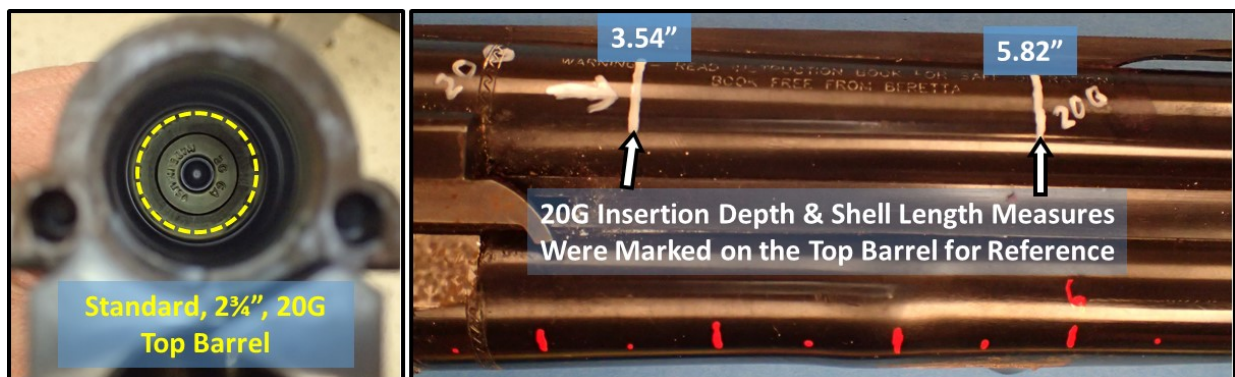


Figure 6. Photos showing the gravity insertion of a standard 2 $\frac{3}{4}$ " 20G shotshell where it came to rest in the forcing cone of the top barrel (yellow dashed circle at left) and the subsequent registration marks applied in white paint marker to indicate the depth and extent of the 20G shell (at right, white arrows; 13131 SAS 2-155 and 13131 SAS 2-167).

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One of the goals of this early stage of the inspection was to determine the region of interest surrounding the burst zone such that when sectioned to open the fracture and expose the ID of the lower barrel, the sections would include and not obliterate any prominent, internal barrel surface features (scratches/witness marks, residue deposits, coloration, lines of demarcation, etc.) for further inspection, testing, analysis, and more importantly to preserve the physical evidence within and on the lower barrel. To this end, a digital imaging borescope with a sidewall-viewing mirror attachment was carefully inserted into the breech end of the lower barrel and the bore or ID surfaces were inspected along the potential region of interest. Figure 7 shows three borescope images captured at ~3.5" (left image) and ~4.0" (middle and right images) with distinct lines of demarcation and color banding and streaking of what appeared to be a powdery, dark gray-to-brown barrel residue material. When viewing the borescope image screen live, during the inspection, it was apparent that there were numerous circumferential and longitudinal scratches or witness marks in this same vicinity, just downstream of ~3.5", although these markings were less apparent in the captured borescope images as these marks were primarily seen as fine reflected lines of light during live borescope imaging.

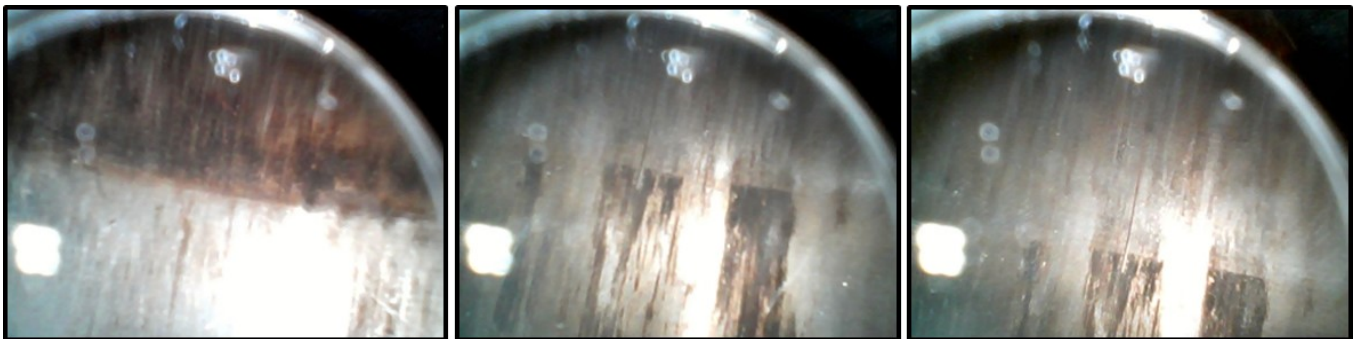


Figure 7. Borescope image captures using a sidewall viewing mirror from inside the lower barrel bore at ~3.5" (left image) and ~4.0" (middle and right images) from the breech end that show distinct circumferential deposits, color streaks/bands and circumferential and longitudinal scratches just upstream of the burst zone.

Figure 8 shows two composited (stitched), wide-angle microscopy images of each side of the marked up, breech end of the subject barrel assembly. The artifact is shown with 1) half-inch hash marks in red, 2) the extent of the 12G, 2 $\frac{3}{4}$ " shotshell also in red, 3) the insertion depth and length of a 20G, 2 $\frac{3}{4}$ " shotshell marked in white, and 4) the proposed sectioning locations marked in yellow. As discussed above, the sectioning locations were selected so as to preserve as much physical evidence within the barrel as possible while minimizing the number of cuts that needed to be made, and minimizing the overall physical size of the resulting sections. Minimizing the number of cuts and the size of the sectioned pieces is a standard goal in a destructive examination as it generates less disturbance of the physical evidence and allows for a wider range of instrumental analysis methods to be used, since most surface analysis methods have limitations on the physical size of samples (*e.g.*, FTIR microscopy and SEM/EDS).

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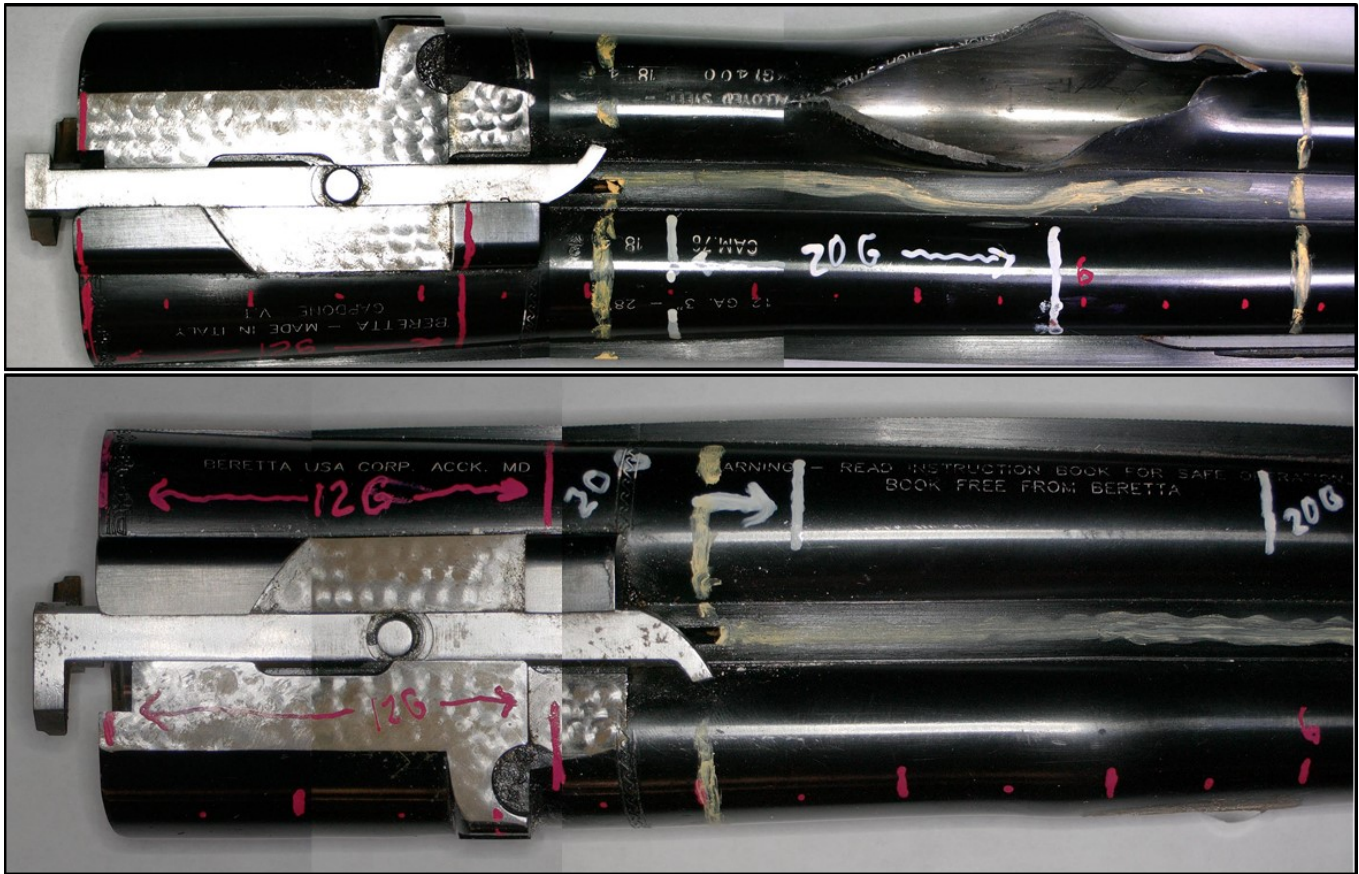


Figure 8. Compositd Keyence microscope images showing the overall registration and sectioning markup of the breech-end of both sides of the subject fore-end barrel assembly prior to beginning the destructive sectioning and analysis. The red paint marks indicated every half inch along the barrel length and the location of a 12G, 2³/₄" shell in the upper barrel chamber, the white paint marks indicated the depth and length of a 20G, 2³/₄" shell, and the yellow paint marks indicated the intended sectioning/cutting locations.

After briefly discussing the rationale for the sectioning marks, the parties present agreed verbally to proceed into the destructive phase of the examination in which the two transverse cuts were made through both the upper and lower barrel tubes as shown in the top photo of Figure 9. These cuts were made using a combination of a tungsten carbide-gritted handsaw blade and a 100-grit, diamond jeweler's wire saw blade. Hand tools were used for these cuts to prevent the buildup of excessive heat that could result from a band saw, reciprocating saw, or spinning wheel cutting tool. Once the two transverse cuts were made and documented, the resulting lower barrel section spanned the lengths from 3.1" to 7.3" as originally measured from the breech end of the barrel assembly. The next two longitudinal or "spine" cuts were made along each of the connecting rib sections to separate the upper barrel from the lower barrel as can be seen on the upper section of the lower left photo in Figure 9. These spine cuts were made with a small abrasive cutting disk using a rotary, Dremel-style tool since the connecting ribs sections were relatively thin and would not buildup excessive heat within the barrel tubes during cutting. The final "butterfly" cuts were made with the diamond-wire jeweler's saw and roughly bisected the lower barrel tube with the first longitudinal cut made along the 3 O'clock position, and then the remaining "tendons" of metal were severed to within ~1/4" of the

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burst zone fracture “roots”, which were then lab-fractured by hand to give the final sections as seen in the lower right photo of Figure 9.



Figure 9. Photos depicting the sectioning sequence to prepare and preserve the regions of interest for further inspection and testing, including the ring bulge, burst zone fracture surfaces, and additional powdery deposits and physical markings just upstream of the burst zone within the lower barrel ID surfaces (CW from top: 13131 SAS 2-300, 13131 SAS 2-347, and 13131 SAS 2-353).

Figure 10 shows photos of the barrel section after making the first two transverse cuts across both barrels, but before subsequent cuts (as viewed from the upstream or breech-ward end of the section). This examination was done in order to re-confirm the prior gauged depth and length position of a gravity-lodged 20G, 2¾“ shell in the top barrel tube as seen on the right side of both photos in Figure 10. Closer inspection of the lower barrel tube, just upstream of the burst zone also confirmed the distinct barrel residue coloration bands and scratches as seen in the right photo of Figure 10 in the location of the yellow and red arrows. Note the apparent similarities of depth between the 20G shell in the upper barrel tube and the color banding in the lower barrel tube at the location of the yellow arrows.

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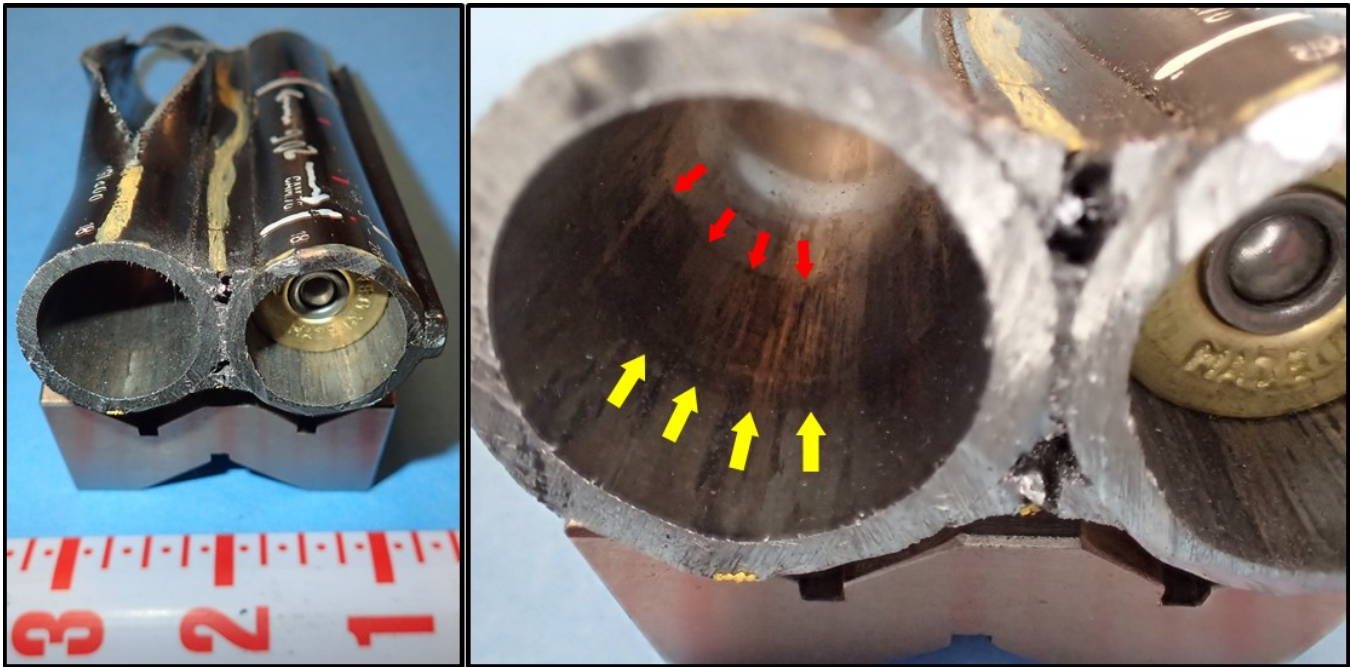


Figure 10. Before sectioning was complete, the insertion of a 20G shell was reconfirmed in the top barrel as shown in the photo at left, and even at this stage, physical banding, streaking, scratching, and discolorations were visible and appeared to correspond closely to the location of the 20G metal head lip (yellow arrows); additional circumferential bands could be seen in several locations downstream of this depth (red arrows; 13131 SAS 2-314 and 13131 SAS 2-320).

Once the final sectioning cuts were completed and the ID surfaces of the lower barrel tube sections could be viewed clearly, the color banding and streaking of barrel residues and the presence of numerous witness marks or scratches became very apparent as seen in the left photo and upper-right and lower-right microscopy images of Figure 11. On closer inspection of the lower barrel sections, the darkest colorations of barrel residues were found in a band upstream of the 3.54" mark (see dashed yellow line annotations in Figure 11), in a very narrow band around the 4.04" mark, and in a more diffuse band around the ring bulge location at 4.9". These darkly colored bands were visually colored dark gray with gray-brown streaking in the longitudinal direction and had a powdery surface texture. In the region between 3.54" and 4.04" there were numerous circumferential and longitudinal scratches/witness marks that again were difficult to photograph or image with the microscope due to the reflective ID surface of the barrel bore (reportedly chromium-plated or "chrome-lined" in Berretta Silver Pigeon barrel bores). This writer also closely examined the fracture surface structures and fracture feature morphology along the entire fracture length in a stereo-optical microscope under a variety of lighting conditions

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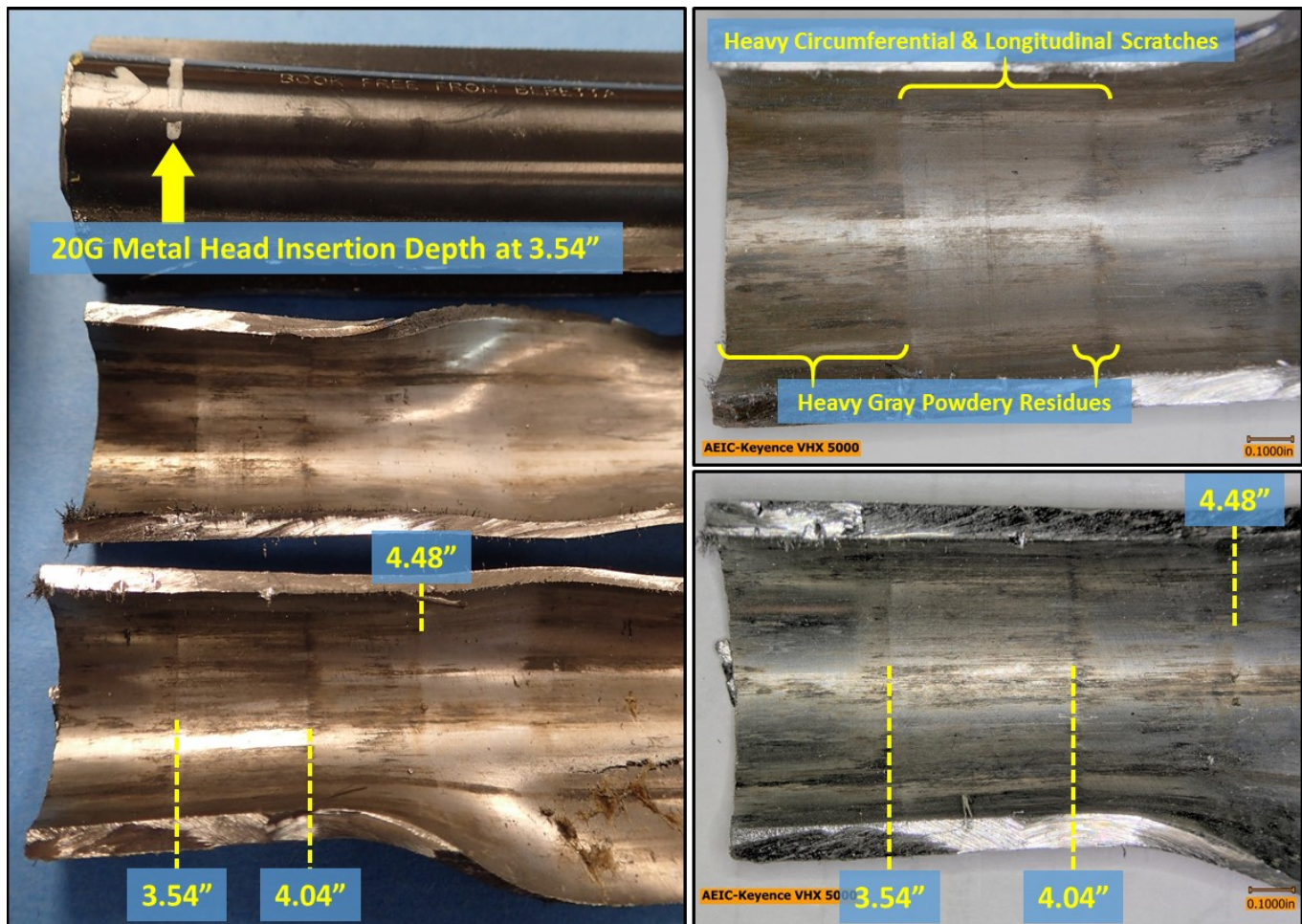


Figure 11. Photo of the fully sectioned and opened lower barrel in the region of interest (at left; 13131 SAS 2-349), which revealed visible bands/streaks of powdery, grey/brown deposits just upstream of the burst zone and ring bulge; similar Keyence microscope images are shown at right with the yellow dashed registration markings based on the distance from the breech end (please note the identical distance measured for the 20G shell insertion depth at the yellow arrow and the most upstream circumferential band at 3.54").

At this stage of the first day of the shotgun examination, all the various barrel assembly sections were bagged with uniquely identifying labels, numbers, and other identifying/descriptive/documentation information. These items along with all other shotgun artifacts were placed back into the gun case and stayed in the possession of Jessica Andrew for transport to the second day examination that was held at Kilgore Engineering. Of the two lower barrel sections from the region of interest, the upper section was chosen and agreed by the parties present to be preserved without further alteration because it retained a number of the well-adhered, yellow, globular barrel residues (see the bottom-most section in the left photo of Figure 11). The lower section from the burst zone and region of interest was to be used in the second day of destructive testing for SEM/EDS imaging and elemental analysis at Kilgore Engineering.

The remainder of the first day of the examination at AEI was then spent conducting infrared spectroscopy analysis of the previously collected samples of yellow and red barrel residues using an FTIR

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spectrophotometer equipped with an attenuated-total-reflectance (ATR) diamond cell for surface contact analysis and also an infrared microscope that allows infrared spectra to be collected in a reflectance mode from an area as small as 10 microns by 10 microns (0.0004" x 0.0004"). Infrared spectral data were also collected from a number of exemplar shotshell materials for qualitative comparison to the subject barrel residues. The top data trace in Figure 12 shows the infrared absorbance spectrum of a skived sample of red plastic tube material from an exemplar Federal Game-Shok, 12G, 2¾", 1 oz., #6 shot, shell captured in reflectance mode in the FTIR microscope. The bottom data trace in Figure 12 shows the infrared absorbance spectra also obtained by the microscopic reflectance mode for the red, fibrillar barrel residue. The spectral similarities are denoted by the double-headed red arrows. It should be noted that it is common for the FTIR spectra of heat-affected/degraded organic materials to increase in complexity (denoted by the appearance of additional absorbance peaks/signals) because high temperatures, pressures, or exposure to combustion gases often leads to chemical reactions within the affected organic materials that give rise to additional infrared absorbances, but some of the spectral bands from the pristine material should still be present in the affected material, albeit with altered spectral intensities (signal/peak heights).

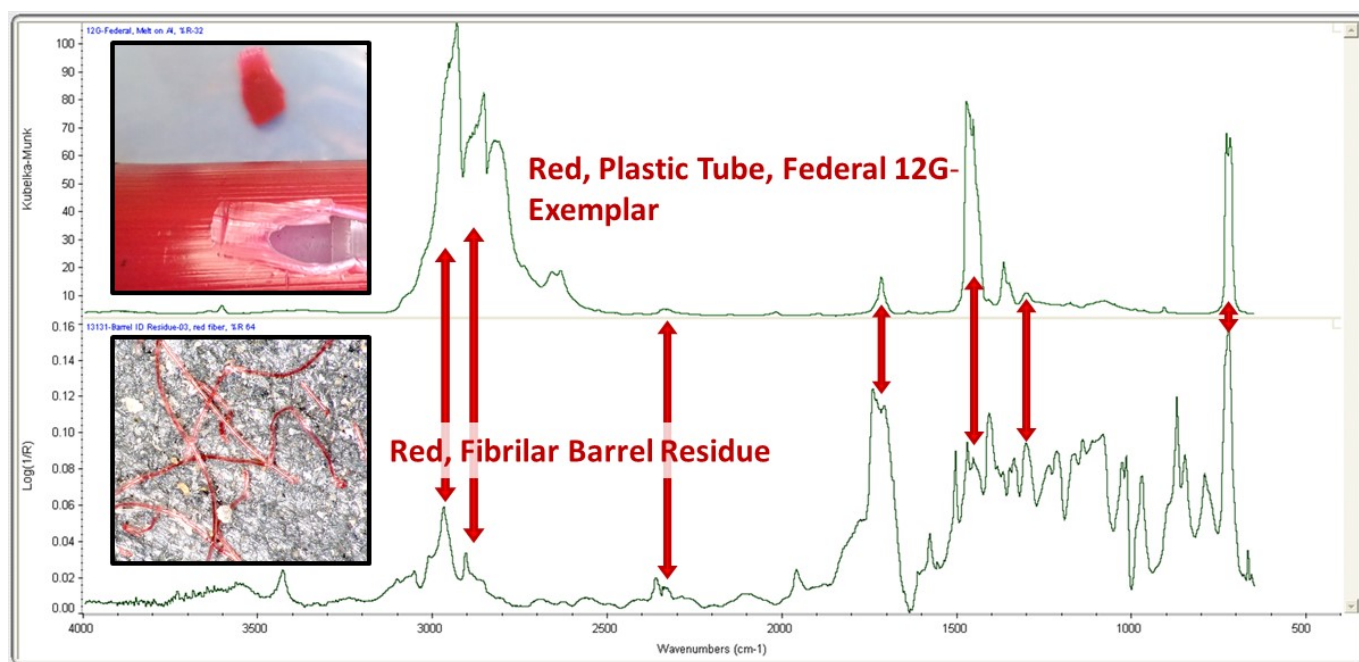


Figure 12. Reflected light microscope infrared absorbance spectra of the exterior surface of the red plastic tube material from an exemplar Federal 12G shotshell (top data trace) compared with the similarly obtained absorbance spectra of the red, fibrillar barrel residues (bottom data trace); the red arrows indicate similar spectral features.

Similarly, the yellow globular residues were analyzed in the ATR-FTIR cell and the infrared absorbance spectra is shown in the bottom data trace of Figure 13. Again this spectrum was complex, but had a number of distinctive broad absorbances that were similar to the ATR-FTIR spectrum of base wad paper fibers, shown in the top data trace of Figure 13 with blue arrows indicating spectral similarities. There were also three distinct absorbances (yellow arrows) that corresponded to the ATR-FTIR spectrum of the yellow

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plastic shotshell tube from a Kent Cartridge “Ultimate Fast Lead”, 20G, 2¾“, 1 oz., #6 shot, shell (middle data trace in Figure 13).

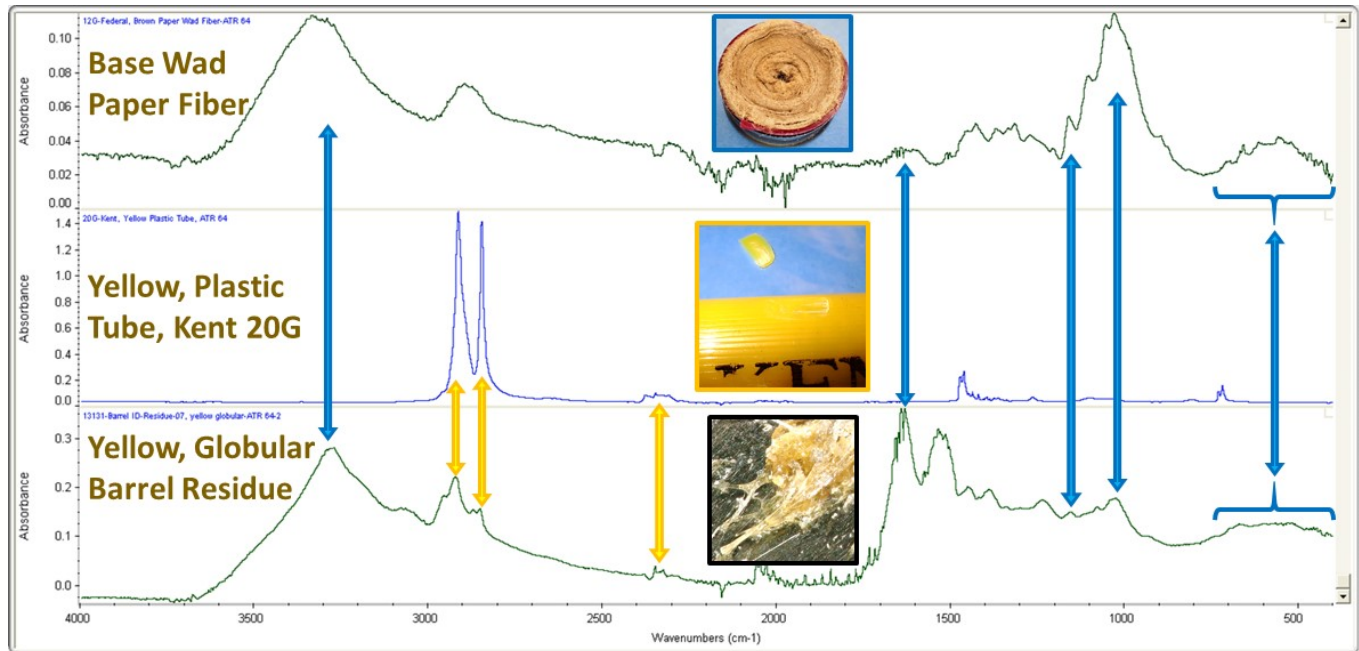


Figure 13. ATR-FTIR absorbance spectra of: the yellow globular barrel residue (bottom data trace), the exterior surface of the yellow plastic tube material from a Kent 20G shotshell (middle data trace), and the paper fibers from the base wad of a Federal 12G exemplar shotshell (top data trace); the blue and yellow arrows indicate similar spectral features.

Shotgun Exam, Day 2 – Sectioning, Micro-Hardness, & SEM/EDS

The second day of the shotgun examination took place on February 7, 2017 and began with a brief discussion among the parties present with Dr. Cornelissen and Mr. Turnquist who assisted with the testing and analysis at Kilgore Engineering. This group discussion included a review of the planned exam protocol steps so that the order of sample preparations and instrument setup was done in an efficient way. The lower barrel section that had been prepared at AEI during the first exam day was also inspected and the group discussed the desired locations for SEM imaging and EDS elemental analysis, and based on these discussions, Dr. Cornelissen and Mr. Turnquist recommended sub-sectioning the barrel section to the region shown in the left photo of Figure 14. Sectioning in this manner preserved the fracture surface intact, but allowed the upstream region of interest where the color banding, scratches, and barrel residues were located to fit into the SEM/EDS sample chamber. The right photo in Figure 15 shows the open sample chamber of the SEM/EDS instrument with the sample stage highlighted by the red dashed ellipse. Again the entire examination proceedings were recorded with video and audio by Ms. Andrew.

The right photo in Figure 14 shows the barrel tube sections that were removed from the upstream end of the remaining length of the barrel assembly from ~7.5” to 8.0”. These barrel sections were then prepared for micro-hardness testing by embedding them in heat-activated resin made for this purpose. The resulting

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“hot metallurgical mounts” were then polished using a series of finer grit polishing wheels to obtain a mirror finish on the barrel tube metal surface where the micro-hardness test instrument was used to make a series of indentations at three circumferential locations while measuring the force and the resulting indentation size. From these three measurements on each tube, the averaged micro-hardness values for a 0.5 kg load was 282 HV for the top barrel and 290 HV for the lower barrel; these micro-hardness values correspond to Rockwell C hardness values of 26 and 27 for the upper and lower barrel tubes, respectively.



Figure 14. On the second day of the joint destructive shotgun exam, the lower barrel section had to be sub-sectioned to the smaller region at lower left in the left photo to fit into the SEM/EDS sample vacuum chamber, and the barrel tube region from ~7.5” to ~8.0” was cut, the upper and lower tubes were separated, hot mounted, polished, and measured for micro-hardness (13131 SAS 3-030 and 13131 SAS 3-022).

Based on the results of the micro-hardness testing, no further metallurgical testing beyond the SEM/EDS elemental analysis was carried out, so the remaining examination time was spent focusing on the SEM/EDS imaging and elemental analysis of the subject barrel section and exemplar shotshell metal head materials. Initially Mr. Turnquist conducted SEM/EDS analysis on exemplar shotshell metal heads to determine the elemental compositions of both the underlying, “base metal” and the outer metallic coating or “wash” compositions. It was generally found that the “base metal” of the exemplar metal heads was steel with an iron content typically greater than 95% in the measured EDS data. “Brass-colored” metal shotshell heads were found to have a surface coating or “wash” that was composed primarily of zinc and copper, whereas the “silver-colored” metal shotshell heads had a surface coating of predominantly zinc or zinc and nickel with iron. Zinc is a typical corrosion inhibitor that is coated on steel and is commonly referred to as “galvanized steel”, and nickel is often added to the galvanizing zinc to “brighten” or increase the shine or luster of galvanized metal finishes since zinc alone tends to form a dull, gray surface appearance over time.

After analyzing the typical metal compositions of the metal shotshell heads, Mr. Turnquist began preparing the sub-sectioned lower barrel artifact pictured in the left photo of Figure 15. Mr. Turnquist recommended that we use a fine-tipped Sharpie® marker to place orientation dots or hash marks on the surface of the sample near where we were interested in capturing images and EDS elemental analysis data. These sharpie marks are visible in the SEM, but are easily removed with a rinse with methanol, so the evidence was minimally altered and it provided easy navigation and tracking of where the imaging and analysis were being conducted on the sample.

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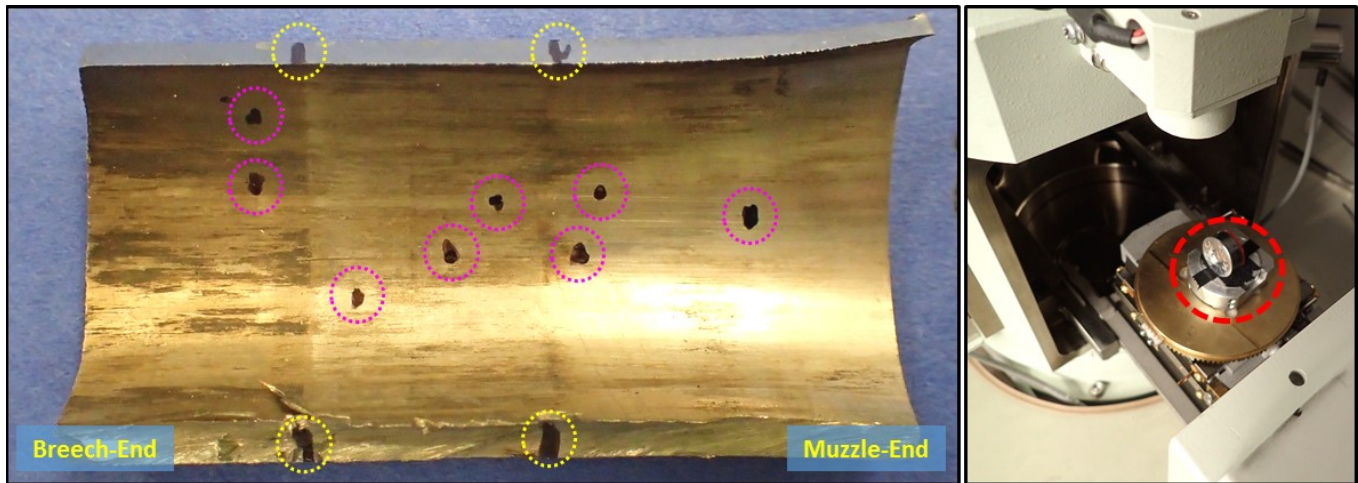


Figure 15. Photo of the lower barrel SEM section with added Sharpie® marker spots (left photo, yellow and pink dashed circles) for indexing and navigation within the SEM sample chamber (right photo) during imaging and EDS testing (13131 SAS 3-035 and 13131 SAS 3-007).

In the left photo of Figure 15, the yellow dashed ellipses highlight the two sets of hash marks for identifying the coloration/residue bands at 3.54" and 4.04", and the pink dashed circles represent navigation points placed near where there was an interest to inspect, image or analyze the ID barrel surface or residues. The main goal of this effort was: 1) to examine the region between 3.54" and 4.04" to identify the presence or absence of witness marks and scratches, 2) to examine a relatively clean portion of the ID surface to identify whether or not the surface was chromium plated or lined, 3) to identify the elemental composition of the dark gray-brown powdery residues, and 4) to identify the presence and location of any zinc, iron, nickel, or copper on the barrel surface that might indicate the prior presence of a 20G barrel obstruction.

The top photo in Figure 16 is provided as a visual reference to indicate where these SEM images were obtained (see yellow inset rectangle), and in this case the goal was to capture a number of images at varying magnifications to identify the circumferential witness marks (vertical lines visible in both lower SEM images of Figure 16) and the longitudinal streaking that had been seen in optical microscopy, but were difficult to capture in the static images.

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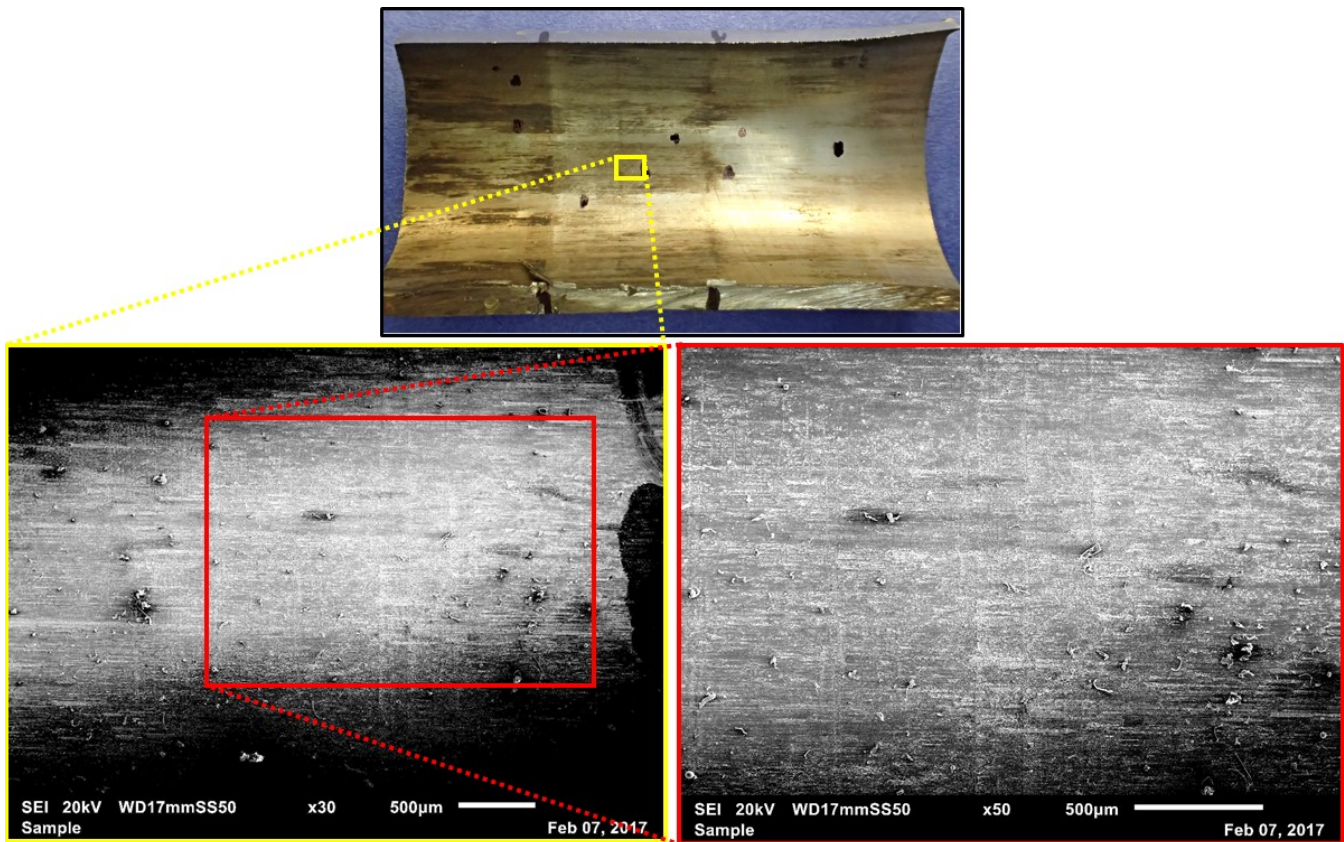


Figure 16. Index photo of the lower barrel section (top, 13131 SAS 3-038) with the inset yellow rectangle corresponding to the SEM image location at lower left, with inset red rectangle corresponding to the SEM image location at lower right showing detailed images of the circumferential scratches (vertical witness marks) and longitudinal streaking of the barrel deposits (horizontal banding).

The red inset rectangle in the top photo in Figure 17 indicates where SEM images and EDS elemental analysis data were obtained on a relatively residue-free portion of the barrel bore surface, and indeed, the SEM image (top, right) shows a relatively residue-free surface with some scratches, and a few spherical particles of gunshot residue. The EDS spectrum for this imaged area is provided in the lower left plot of Figure 17, with the quantitative results reported in the table at lower right as Mass%, which identified the presence of carbon, oxygen, and chromium, with chromium at 87% (see pink dashed rectangle). This tentatively confirmed the reported information that the subject barrel bores were chrome-lined or plated.

It should also be noted that carbon, oxygen, and sometimes trace sulfur will often be present inside a used firearm barrel bore because the propellants, wads, projectile materials, and gun oils can leave a remnant trace of carbon and sulfur depending on the types of ammunition and cleaning products used, and oxygen will always be present on a metallic surface to some extent where a passivating layer of, in this case, chromium oxide was present and expected.

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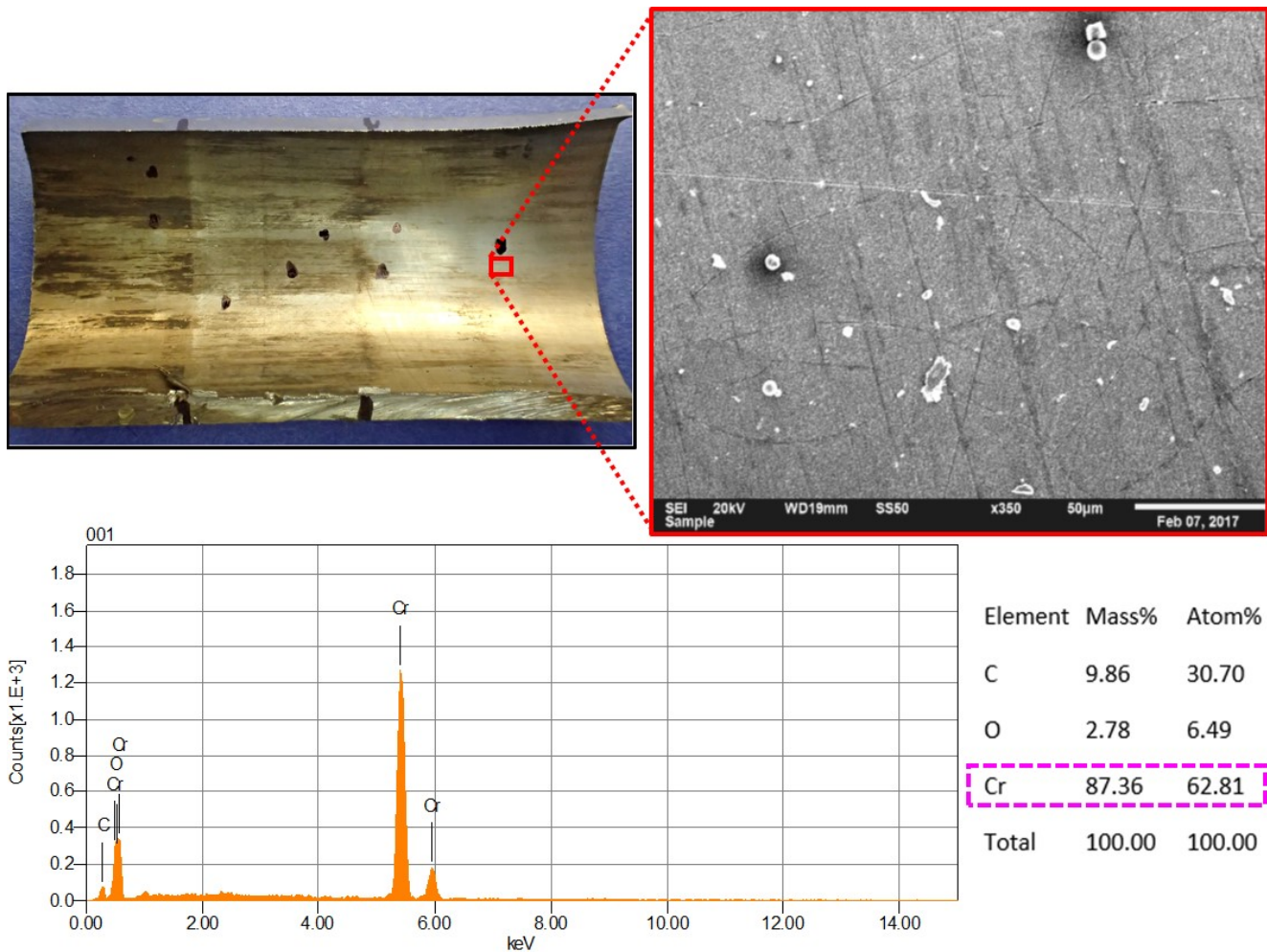


Figure 17. Index photo of the lower barrel section (top left, 13131 SAS 3-038) with the inset red rectangle corresponding to the SEM image location at top right that showed a relatively clean area of barrel ID surface where the EDS data (EDS 001) confirmed chromium as the only heavy element present (Cr, pink dashed rectangle).

The red inset rectangle in the top photo in Figure 18 indicates where SEM images and EDS elemental analysis data were obtained on an area of the barrel bore surface with some light residue and scratches, and was located just downstream of the 4.04" band. The SEM image (top, right in Figure 18) shows a bore surface region with heavy circumferential scratches, a few longitudinal scratches, and a relatively light coating of residue material. The EDS spectrum for this imaged area is provided in the lower left plot of Figure 18, with the quantitative results reported in the table at lower right as Mass%, which identified the presence of chromium at 87% and lead at 4.5% (see pink and green dashed rectangles).

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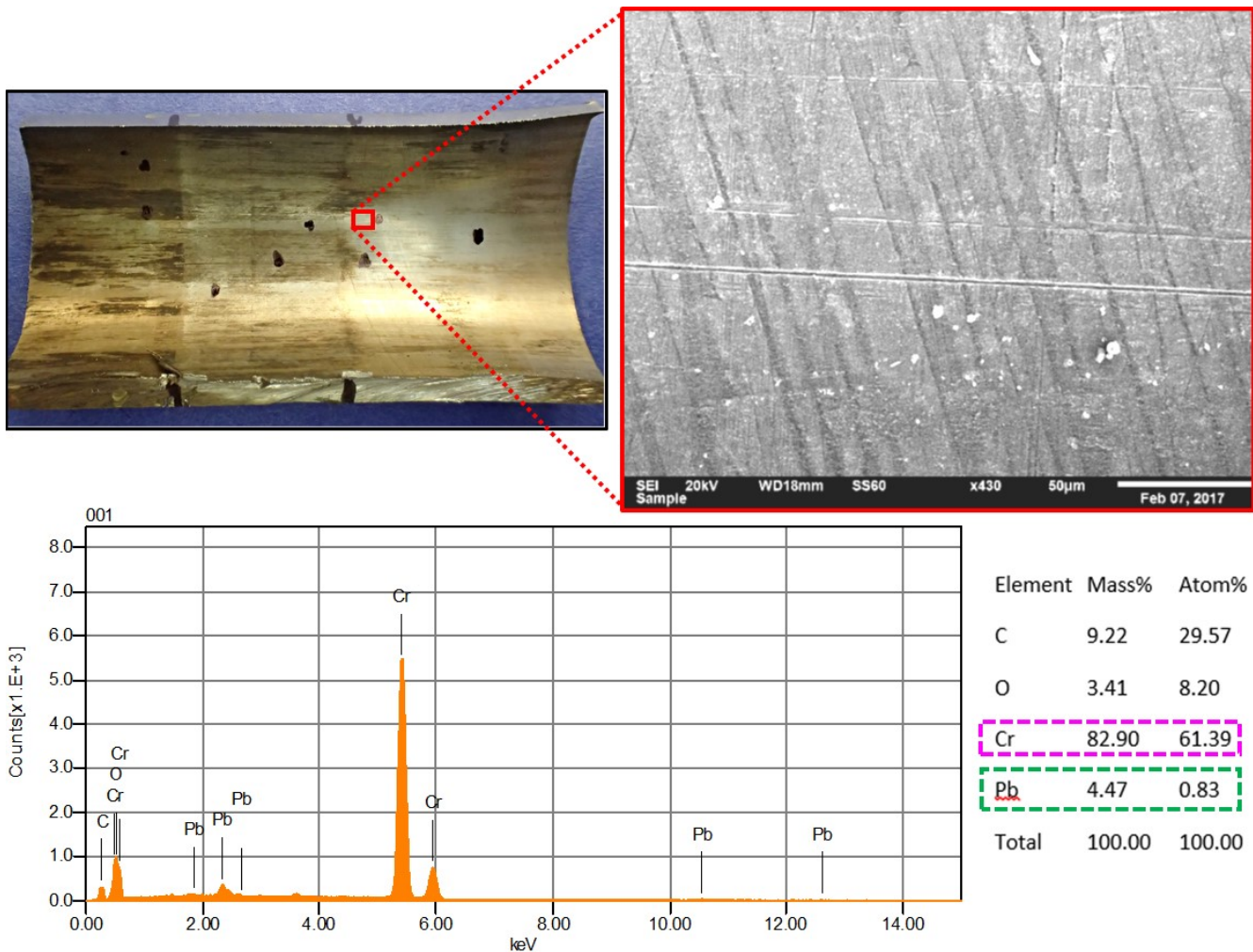


Figure 18. Index photo of the lower barrel section (top left, 13131 SAS 3-038) with the inset red rectangle corresponding to the SEM image location at top right that showed an area of barrel ID surface with light residues, but heavy scratching; the EDS data (EDS 002) confirmed predominantly chromium (Cr, pink dashed rectangle) with just under 5% lead present (Pb, green dashed rectangle).

The red inset rectangle in the top photo in Figure 19 indicates where SEM images and EDS elemental analysis data were obtained on the darkly colored circumferential band located at 4.04". The SEM image (top, right in Figure 19) shows a heavy buildup of residues that were concentrated in both circumferential and longitudinal bands. The EDS spectrum for this area is shown in the bottom of Figure 19, and identified less chromium at 35% and much more lead at 32% accompanied by antimony (Sb, 4%) and arsenic (As, 0.6%) (see pink and green dashed rectangles, lower right, Figure 19). It should be noted that lead, antimony, and arsenic are all elements that are commonly found within the composition of "lead shot" and other projectile types. The reduced amount of chromium identified in this EDS spectrum is due to the bore surface being coated and "shielded" by the presence of the other heavy element residues on the bore surface, so this data should not be misconstrued to mean that the bore wall contained less chromium, rather, its presence was shielded or effectively diluted by the residue deposits since EDS only analyzes surface compositions.

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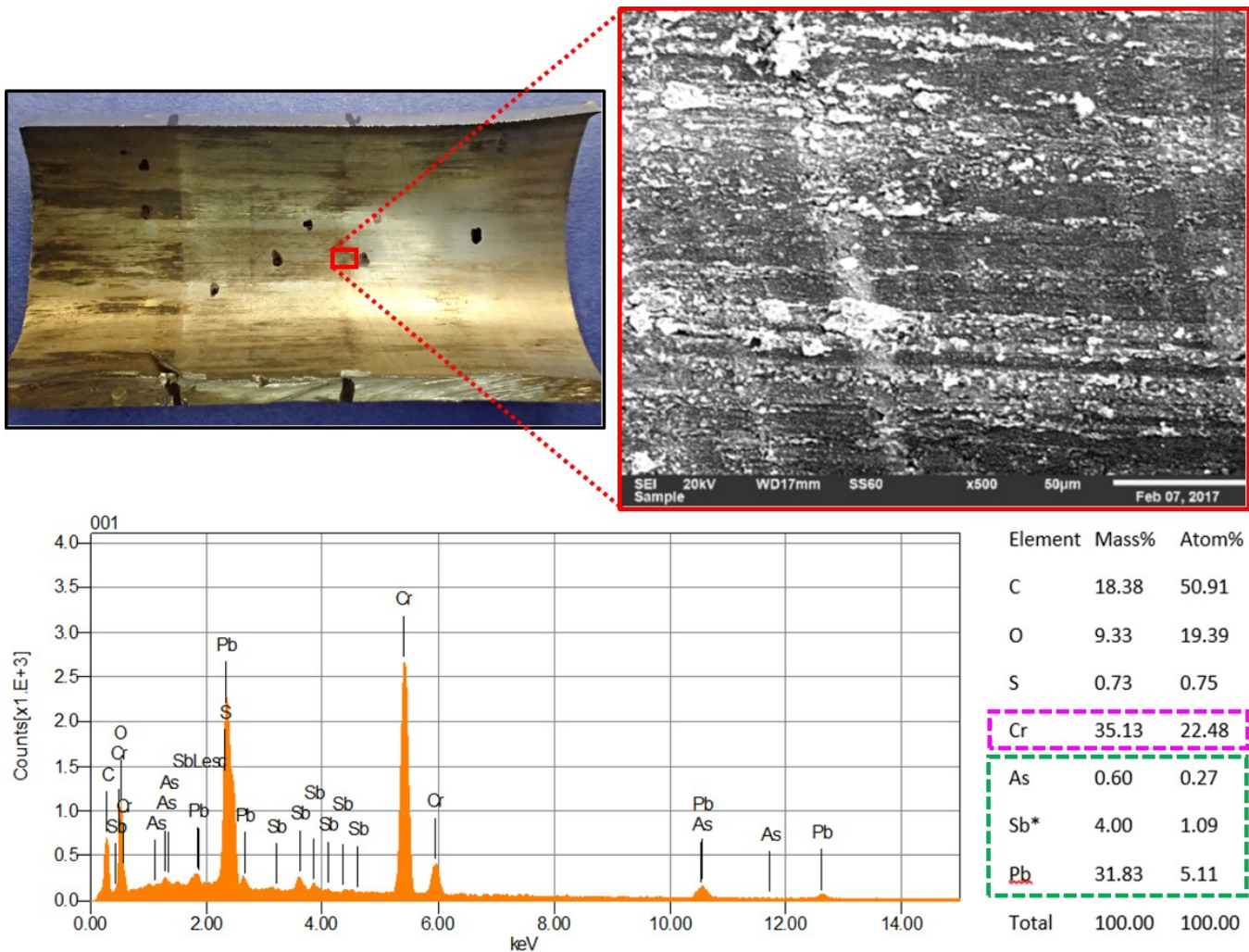


Figure 19. Index photo of the lower barrel section (top left, 13131 SAS 3-038) with the inset red rectangle corresponding to the SEM image location at top right that shows a high magnification image centered on the darkly-colored circumferential band at 4.04" with visible, heavy, gray powdery residue and longitudinal deposit streaking; the EDS data (EDS 003) identified less chromium (Cr 35%, pink dashed rectangle) from the barrel surface, but significantly more lead (32%) accompanied by antimony and trace arsenic (Pb, Sb, As, green dashed rectangle).

The red inset rectangle in the top photo in Figure 20 again indicates where the SEM images and EDS elemental analysis data were obtained on the lightly colored circumferential band located just downstream of 3.54". The SEM image (top, right in Figure 20) shows relatively light scratches in the circumferential direction, but also exhibits residue streaks and bands in the longitudinal direction, looking like the bore wall residues were possibly sheared in the longitudinal direction. The EDS spectrum for this area is shown in the bottom of Figure 20, and identified chromium at 65% and lead at 8%, but also identified both zinc and iron at ~1% each (see pink, blue, and green dashed rectangles, lower right, Figure 20). Neither zinc nor iron are associated with projectile materials, so their presence was noteworthy, particularly given that they were found just downstream of where a 20G metal head would initially hang up in the subject barrel.

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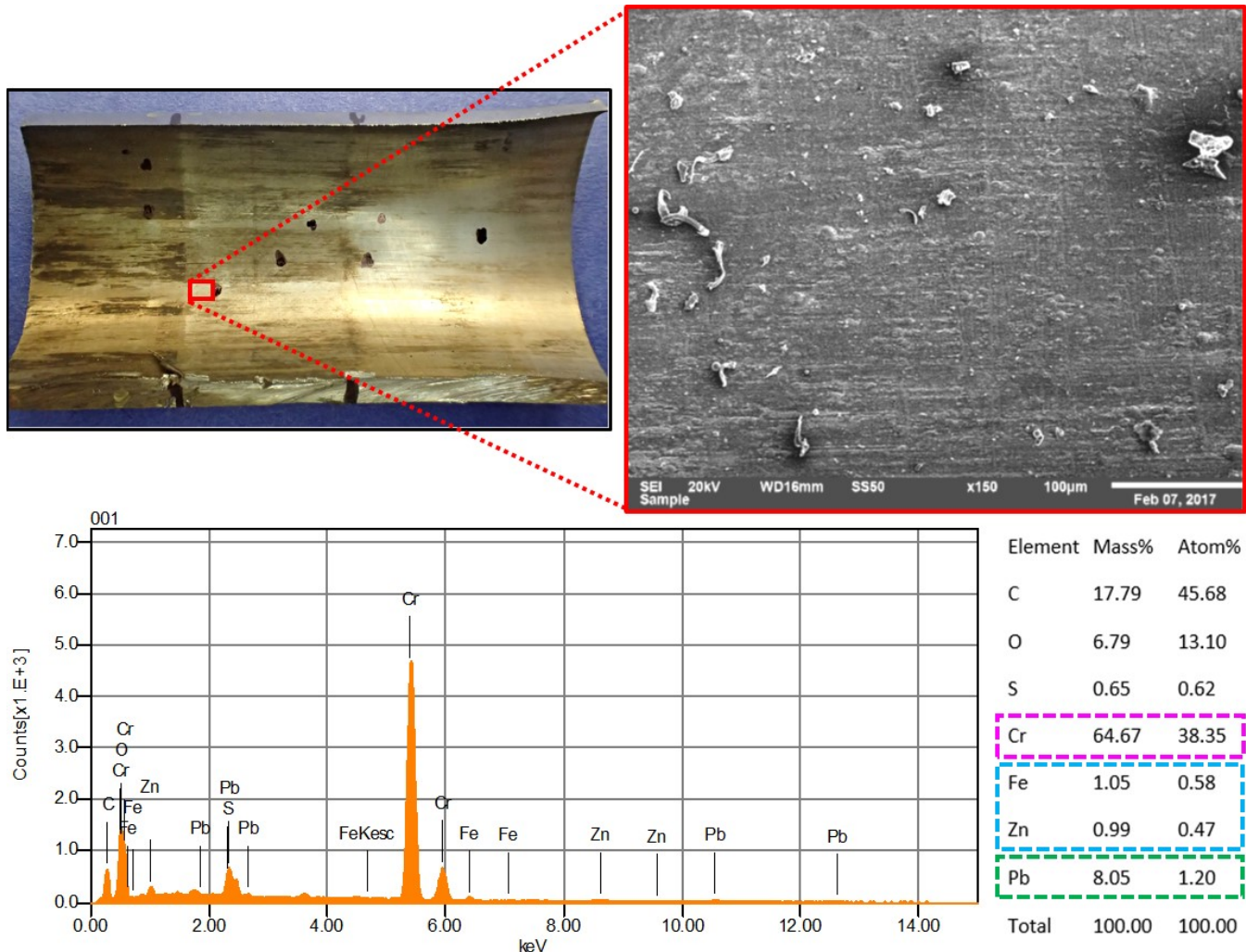


Figure 20. Index photo of the lower barrel section (top left, 13131 SAS 3-038) with the inset red rectangle corresponding to the SEM image location at top right that shows the area of the barrel surface just downstream of the darkly-colored circumferential band at 3.54" that registered with the exact location where a 20G head would hang-up within the forcing cone of the barrel; the EDS data (EDS 006) identified predominantly chromium and lead (Cr 65%, Pb 8%, pink and green dashed rectangle, respectively), but also identified iron and zinc, both at ~1% (Fe, Zn, blue dashed rectangle).

Figure 21 is set up slightly different than the SEM/EDS figures above, because it was designed to show the transition of the barrel bore wall surface on either side of the distinct band at 3.54", which was one of the most prominently visible physical features within the bore, just upstream of the burst zone, and also coincided with the location where a 20G shell would initially hang up in the subject bore. The blue rectangle in the top photo of Figure 21 shows the location of the SEM image in the bottom middle (blue frame) and was obtained at 50x magnification. The gold rectangle in both the top photo and bottom middle SEM show where the bottom left SEM image was captured (gold frame) at 250x magnification. Similarly, the red rectangle in the top photo and bottom middle SEM show where the bottom right SEM image was captured

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at 100x magnification. Describing this figure another way would be that the middle SEM shows the areas on either side of the 3.54" position with the left SEM showing the surface upstream of 3.54" and the right SEM showing the surface downstream of 3.54". Obviously, these two surface regions are very different in appearance with the upstream region exhibiting extremely heavy lead deposits at 57% with only 4% chromium showing through the lead residues (see bottom left SEM with EDS inset table). The downstream region by contrast looks scraped or sheared in the longitudinal direction with 56% of the chromium wall showing through the banded deposits identified as 21% lead, 3% zinc, and just under 1% nickel (see bottom right SEM with EDS inset table). It is unexpected to again find zinc along with nickel, but the identification of first, zinc with iron (in Figure 20 above) and second, zinc with nickel (in Figure 21 below) only occurred in the light colored band just downstream of 3.54".

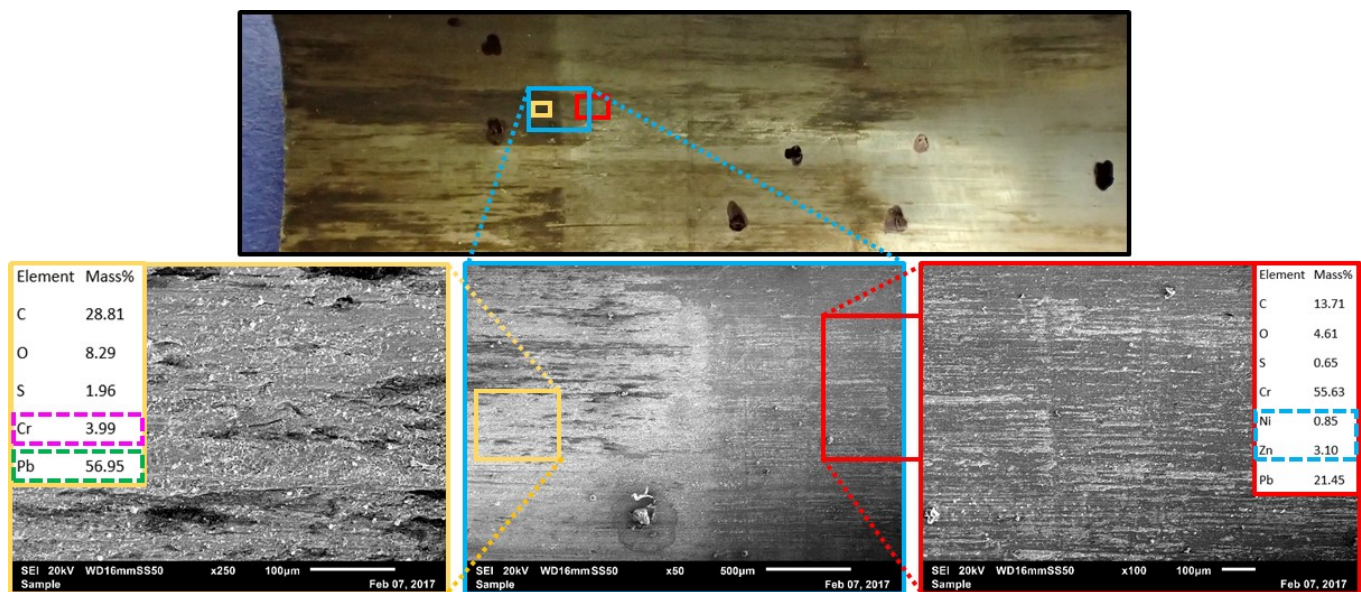


Figure 21. Magnified index photo of the lower barrel section (top middle, 13131 SAS 3-038) with the inset colored rectangles corresponding to the SEM images in the bottom row. The lower middle SEM image (blue frame) shows a 50x magnified view of the two barrel surface zones on either side of the 3.54" circumferential band. The lower left SEM image (gold frame) shows a 250x view of the barrel surface just upstream of 3.54" with the inset EDS data identifying 57% lead and only 4% chromium at this location (EDS 007B). The lower right SEM image (red frame) shows a 100x view of the barrel surface just downstream of 3.54" with the inset EDS data identifying 56% chromium, 21% lead, 3% zinc, and 0.85% nickel (EDS 007A).

Ammo Artifacts Exam – Examination, Measurement, & FTIR Analysis

On June 14-16, 2017, this writer conducted a non-destructive examination of three envelopes of shotshell artifacts that were sent by Lance Andrew's office. These artifacts had previously been examined and reported on by Mr. Roster, however, this was the only occasion on which this writer was able to view or examine these shotshell artifacts. Figure 22 shows photographs of the items with the leftmost photo showing the envelope that contained the "8009 spent hull" and was, the middle photo showing what this writer will call the "separated hull" artifact, and the two rightmost photos showing the collection of some un-bagged and other bagged spent shotshell items. The "8009 spent hull" and was reportedly collected on the day of the incident by Stephanie Thompson who was the hunting guide at the scene, the large

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collection of assorted shotshell hulls and wads was reportedly collected near the scene of the incident on June 3, 2015, and the “separated hull” was recovered on June 12, 2015 by Mr. Barben (~7 months after the incident and reportedly after the incident field had been treated with a controlled burn on an unknown date, post-incident).



Figure 22. Photos of the “8009” hull artifact as received and examined on June 14, 2017 (13131 SAS 4-021, 13131 SAS 4-024, 13131 SAS 4-029, and 13131 SAS 4-047).

All of the above artifacts were visually examined with and without magnification, photographically documented, and in the case of the “8009 spent hull” and the “separated hull”, were also documented with digital optical microscopy, microscopic metrology, and 3D profiling. The exterior surface of the red plastic tubes of both the “8009 spent hull” and the “separated hull” were also analyzed by ATR-FTR for comparison with the exterior red plastic tube of an exemplar Federal “H121 6” shell.

Figure 23 show photos of the “8009 spent hull” artifact as received and examined by this writer at AEI. Figure 24 shows similar photos of the “separated hull” artifact as received and examined by this writer. With close visual and microscopic examination under a variety of lighting conditions, the “separated hull” artifact does have printed markings which resemble the markings of a Federal “H121 6” shell.



Figure 23. Photos of the “8009” hull artifact as received and examined on June 14, 2017 (13131 SAS 4-172, 13131 SAS 4-177, 13131 SAS 4-187, and 13131 SAS 4-173).

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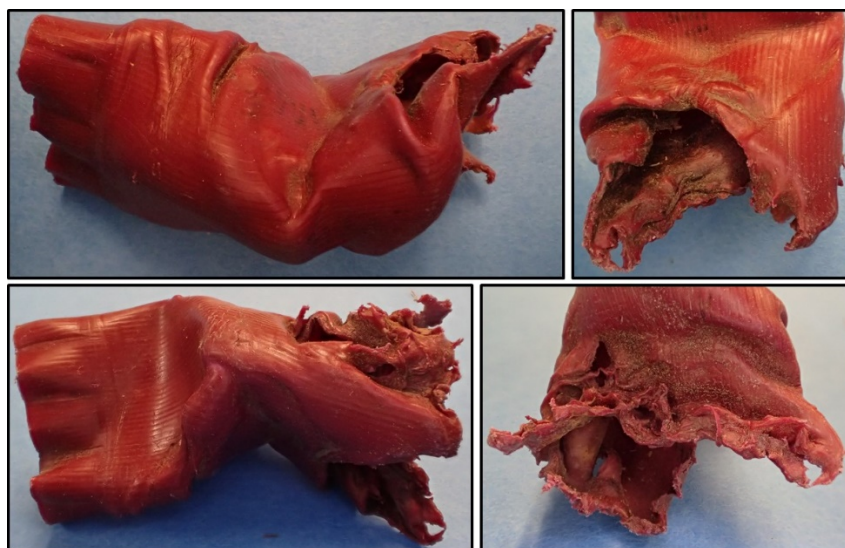


Figure 24. Photos of the separated hull artifact as received and examined on June 14, 2017 (13131 SAS 4-124, 13131 SAS 4-140, 13131 SAS 4-126, and 13131 SAS 4-118).

In Mr. Roster's ammunition report (dated "11-20-2016"; also marked JSB000341-378) he attributed the roughly damaged portion of the "separated hull" artifact that was at the opposite end from the crimp end (see the lower right photo of Figure 24) as having possibly come from the impact of #6 shot pellets. Mr. Roster further claimed that what he termed an "indent", "dimple", or "pit" located at the position in the blue dashed rectangle of Figure 24 was perfectly sized and cupped to fit a #6 shot pellet. During this writer's examination of the "separated hull" artifact, an optical 3D profile was prepared from high-resolution Z-stacking images in the Keyence VHX-5000 microscope, and the rightmost image shows a rotated 3D reconstruction of the artifact "dimple". Given the undocumented nature of where and when this artifact was recovered, there are too many possibilities for this writer to consider on how this artifact could have lost its metal head, become kinked, damaged, deformed, and wrinkled.

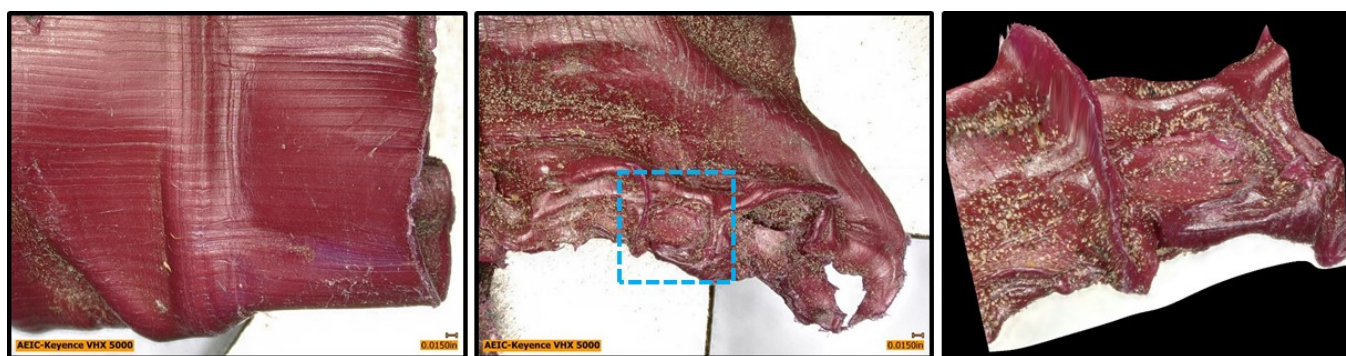


Figure 24. Keyence digital microscopy images of the separated hull artifact viewing magnified views of the crimp end (left), the separated head end (middle) with a highlight of the feature that Mr. Roster attributed to a shot impression (blue dashed rectangle), and the 3D projection of this region (right).

The final series of non-destructive analyses that were conducted as a part of this exam was to obtain ATR-FTIR spectral data from the two hull artifacts. Figure 25 shows the absorbance spectra for the exterior red plastic tube materials of an exemplar Federal "H121 6" shell, the exterior of the "8009 spent hull", and the exterior of the "separated hull". Other than the signals marked by the red arrows in both the artifact items,

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the principle infrared absorbances match the exemplar material.

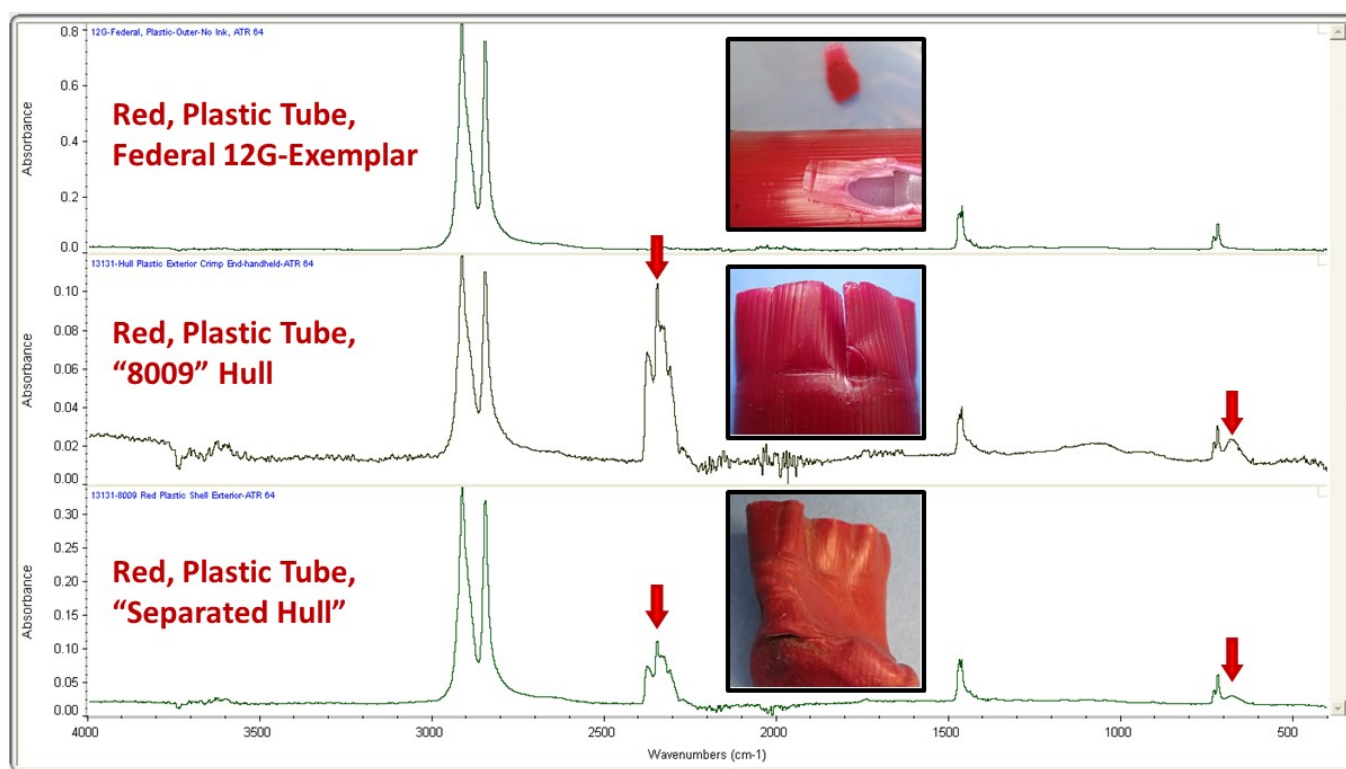


Figure 25. ATR-FTIR absorbance spectra of: the exterior red plastic tube material from a Federal 12G exemplar (top data trace), the exterior red plastic tube material from the “8009 spent hull” (middle data trace), and the exterior red plastic tube material from the “separated hull” (bottom data trace); the red arrows indicate unidentified absorbance signals that differed from the exemplar spectrum.

DISCUSSION

During this writer’s examination, testing, and analysis of the subject shotgun artifacts, there were no indications of metallurgical or corrosion-based deficiencies in the vicinity of the barrel burst zone. The ring bulge, location and extent of the burst zone, and fracture surface features all indicated a monotonic, ductile overload event, meaning that the barrel burst because there was a single, extreme pressure spike event that exceeded the strength of the barrel when the incident took place. The “separated hull” artifact was not collected in accordance with the recommended guidelines for forensic investigations and the collection of physical evidence provided in ASTM Standards E1188, E1020, and E1492, or NFPA 921, and is therefore of suspect origin and should not be regarded as valid evidence in the investigation of this matter.

The primary physical evidence that is not in question in this matter is Mr. Barben’s shotgun. From the gun barrel assembly alone the physical evidence includes: the barrel ring bulge, burst extent, burst location, burst fracture surfaces, yellow and red barrel residues, barrel bore witness markings, scratches, residue deposits, deposit locations, and deposit compositions. Additionally, the multiple lines of materials testing and analysis that were carried out during this investigation all indicated that a 20G round was the source of

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the barrel obstruction that led to the barrel burst in this incident. The appearance and infrared spectra of the yellow globular barrel residues were consistent with a combination of heat-affected, 20G shotshell tube plastic combined with the base wad paper fibers used in the construction of many different shotshell rounds. The appearance and infrared spectra of the red fibrillar barrel residues was also consistent with heat-affected, red 12G shotshell tube material.

The strongest indications of a 20G barrel obstruction came when the bore of the lower barrel in the burst zone was sectioned and opened, and there were distinct bands of residues at the precise location where a 20G shell would lodge under gravity in the subject barrel, at 3.54” as measured from the barrel breech. The band of circumferential scratches, and longitudinally streaked or sheared residues in the bore section between 3.54” and 4.04” is precisely the kind of witness markings that would be expected in a 20G obstruction event. These markings are formed because at the moment of firing the normally-chambered 12G shell, the pressure would build and force the 20G shotshell forward in fits and starts. Forcing the 20G shotshell forward into an ever-smaller bore diameter causes the metal head to scrape against the sides of the bore, leaving deposits of disintegrating projectile materials on the upstream side of the metal head, and also leaving deposits of the metal head itself on the bore wall near this location. Eventually as the 20G obstruction is unable to push any farther forward, there would be a buildup of enough pressure and temperature to melt and fragment many of the materials, burst the barrel, and release the pressure, heat, and fragmented contents of the barrel through the barrel burst zone.

The EDS data in Figure 25 is provided as an example of a “silver-colored” metal head material that is common in many types of shotshell rounds (.410, 20G, 12G, 10G, etc.) where solid brass (copper and zinc) has been replaced with steel coated with an anti-corrosion coating that typically contains significant quantities of zinc, iron, and nickel, a composition often used to “brighten” galvanized steel. Because of the expense of copper, more and more ammunition manufacturers use steel instead of brass. Throughout the SEM/EDS testing, only two locations were found that showed deposits of zinc and iron or nickel (see Figures 20 and 21 above), and that was just downstream of 3.54” and exactly where the deposits of a 20G obstruction would leave deposits of its metal head material on the bore of the subject barrel. Since there were no locations where copper was identified on the bore surface, it is likely that the obstructing 20G shotshell possessed a brightened galvanized steel head that was composed of zinc, iron, and nickel.

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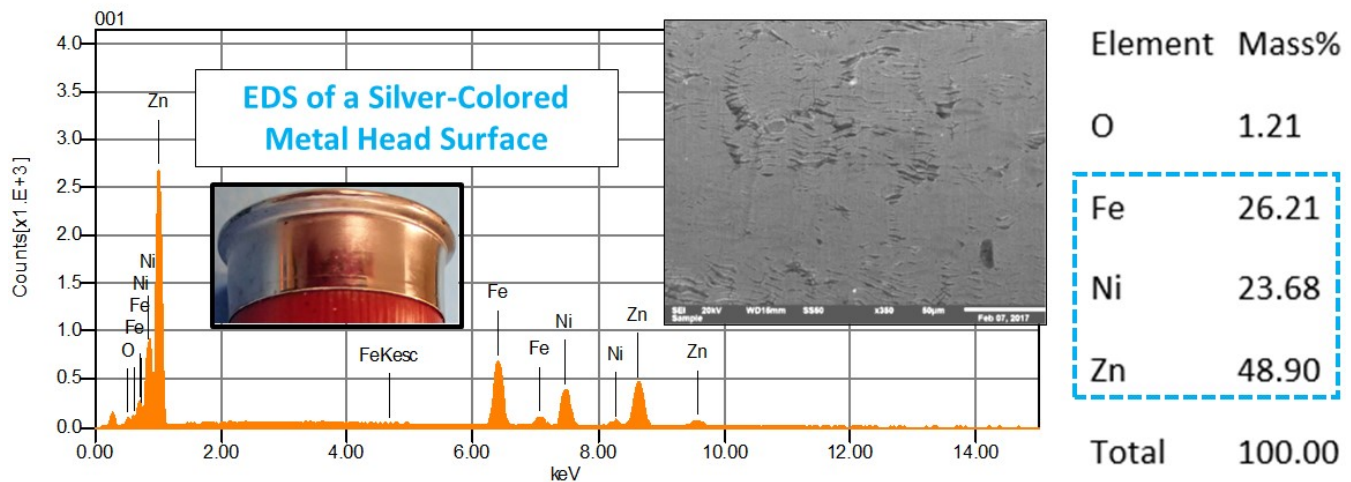


Figure 25. EDS data obtained on the exterior surface of a Federal, silver-colored metal head identifying zinc, nickel, and iron (Zn, Ni, Fe, blue dashed rectangle) with inset photo and SEM image.

At this stage of the investigation, this writer has found multiple lines of inquiry, observations, physical evidence, and analysis results that all point in the direction of a 20G barrel obstruction as the cause of this failure. Despite Mr. Barben's and other witnesses accounts of the incident, and despite the undocumented and improper collection of the "separated hull" artifact (and Mr. Roster's analysis of it), it is this writer's opinion that the lower barrel of the subject Berretta Silver Pigeon II shotgun (SN U30798B) failed on October 30, 2014, as a result of an improperly loaded 20G round that lodged in the forcing cone region of the lower barrel and created a barrel obstruction.

CONCLUSIONS

The results of the investigation performed by AEI Corporation indicate the following:

1. The subject shotgun barrel burst as a result of a monotonic ductile overload event arising from a barrel obstruction.
2. The results of micro-hardness testing and the examination of the barrel burst zone in optical and electron microscopes indicated that the lower barrel of the subject shotgun was free from metallurgical or corrosion defects.
3. The ring bulge location, burst zone location and extent, bore residue/deposit locations, bore witness marks, and bore deposit compositions were all consistent with a 20G shotshell as the source of the barrel obstruction.
4. The results of the infrared spectroscopy analysis of the exemplar Federal "H121 6" shotshell tube indicated it was composed of polyethylene or polypropylene or a copolymer of each.
5. The "separated hull" artifact was not collected according to the ASTM and NFPA standards for the collection and preservation of evidence, and is unlikely that it is related to this case.

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The opinions expressed in this report are based upon this writer's education, training, and work experience. The opinions are also based upon a reasonable degree of scientific and engineering certainty and the information available to this writer at the time the report was authored. This writer reserves the right to modify and/or supplement these opinions should new information become available. The investigation, methodology, analysis, findings, conclusions, and opinions detailed in this report are consistent with, and based upon, the recognized and accepted standards and practices of physical component failure investigation and fire and explosion investigation including, but not limited to, applicable sections of ASTM Standards: E 620, E 678, E 860, E 1020, E 1188, E 1459, E 1492 and E 2332, and the 2014 Edition of National Fire Protection Association (NFPA) 921, *Guide for Fire and Explosion Investigations*.



Advanced Engineering Investigations

SHAWN A. SAPP, Ph.D.

Dr. Sapp has been a practicing materials scientist and analytical chemist since 2002. He is ASM Certified in Fracture Mechanics, Fractography, and Failure Analysis to determine the origin and cause of failures in metals, ceramics, plastics, and composites. He is a highly experienced electrochemist and metallographer with over twelve years of experience in industrial, aerospace, marine, and electronics corrosion testing and surface analysis. His knowledge of process chemistry spans from pilot-scale pharmaceutical synthesis and bio-conversion, to full-scale petro-chemical production. He has expertise in investigating accidents in the chemical process and oil & gas industries; analyzing flammable and combustible liquid-related accidents; and investigating carbon monoxide and chemical release or exposure-related incidents.



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Director of Research, *Tusaar Corporation*, 2014 to 2015

Senior Chemist, *TDA Research Inc.*, 2002 to 2014

EXPERIENCE

Dr. Sapp has spent the majority of his career applying his knowledge of chemistry, physics, and engineering to the investigation and analysis of a wide variety of surfaces and materials. His early career was spent developing new electronic, functional, polymeric, composite, synthetic, natural, bio-degradable, or nano-materials for advanced technologies. His experience gives him a solid working knowledge that can be applied to forensic engineering. Dr. Sapp is an expert in optical & electron microscopy, a certified user of the electron microscopy center at Colorado School of Mines on a variety of FE-SEM, TEM & EDS equipment, and a wide variety of chemical composition and physical property analysis techniques, including GC-MS, MALDI-MS, ICP-MS, HPLC, Gel Permeation Chromatography, DSC-TGA, DMA, FTIR, Optical Emission Spectroscopy, X-ray Fluorescence Spectroscopy, and X-ray Diffraction.

Dr. Sapp has nearly twenty years of experience in chemical laboratory hygiene, best practices and safety, including knowledge of the flammability characteristics of liquids, powders, plastics, composites, and structural materials; testing, safe handling, destruction, and disposal of highly reactive, energetic materials and pyrophoric reagents. He has conducted hazard analyses of materials, equipment and processes, designed, analyzed and implemented quality control experiments, and authored safe operating procedures to comply with OSHA, EPA, DOT, and local county and municipality regulations regarding the safe handling and disposal of hazardous materials.

PUBLICATIONS

List available on website, www.AEIengineers.com

AFFILIATIONS

American Chemical Society (ACS)

American Society of Metals (ASM International)

Materials Research Society (MRS)

National Association of Corrosion Engineers (NACE International)

Chemists Without Borders "Humanitarian Solutions Worldwide"

SHAWN A. SAPP, PH.D. PUBLICATIONS

S.A. Sapp, et al., *Rapid Switching Solid-State Electrochromic Devices Based on Complementary Conducting Polymer Films*, Adv. Mater., 8, p.808-811 (1996).

S.A. Sapp, et al., *High Contrast Ratio and Fast-Switching Dual Polymer Electrochromic Devices*, Chem. Mater., 10, p.2101-2108 (1998)

S.A. Sapp, et al., *Using Template-Synthesized Micro- and Nanowires as Building Blocks for Self-Assembly of Supramolecular Architectures*, Chem. Mater., 11 p.1183-1185 (1999)

S.A. Sapp, et al., *Substituted Polypyridine Complexes of Cobalt (II/III) as Efficient Electron-Transfer Mediators in Dye-Sensitized Solar Cells*, J. Amer. Chem. Soc., 124 p.11215-11222 (2002)

S.A. Sapp & M. Elliott, *Solid-State Solutions: Polymer-Encapsulated Reverse Micelles Containing Dye Solutions*, Chem. Mater., 15 p.1237-1241 (2003)

S.A. Sapp et al., *Work Function and Implications of Doped Poly (3, 4-ethylenedioxythiophene)-CO-Poly(ethylene glycol)*, Appl. Phys. Lett., 88 152107 (1-3) (2006)

Z.J. Jason, J.L. Schumacher, & **S.A. Sapp**, *The Fire and Explosion Risks Associated With Cannabis/Hash Oil Extraction – A Technical Guide For A Forensic Investigation*, International Symposium on Fire Investigations Science and Technology, National Association of Fire Investigators, Scottsdale, AZ, September 2016



Testimony Record of Shawn A. Sapp

Four Year Testimony Record

J/N	Date	Depo, Trial, Arb	Case No.	Court	Case Name	Pl/Def	Description
12346	2/16/2017	D	CI 15-168	District Court of Box Butte County, Nebraska	Sandy Todd and Cindy Zurn, Personal Representatives of the Estate of Patricia Vogel, Deceased; and Cindy Zurn, individually vs. Jack's Refrigeration, Inc.	Def	EXPL